Environment Agency

using science to create a better place

Best practice techniques for environmental radiological monitoring

Science Report – SC030308/SR

SCHO0407BMNL-E-P

ea/br/e/sci/v1

The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

Published by:
Environment Agency, Rio House, Waterside Drive,
Aztec West, Almondsbury, Bristol, BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
www.environment-agency.gov.uk

ISBN: 978-1-84432-746-1

Further copies of this report are available from:
The Environment Agency's National Customer Contact Centre by emailing:
enquiries@environment-agency.gov.uk
or by telephoning 08708 506506.

Author:
Leonard, K. S

Dissemination Status:
Publicly available

Keywords:
Radiological monitoring, Best Practice, Standards, Guidelines, Sample Collection, Sample Preparation.

Research Contractor:
Cefas
Pakefield Road
Lowestoft Suffolk
NR33 0HT
Tel: 0152 562244

Environment Agency's Project Managers:
Rob Allott, Jane Rowe and David Copplestone

Science Project Number:
SC030308

Product Code:
SCHO0407BMNL-E-P

Science at the Environment Agency

Science underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us and helps us to develop monitoring tools and techniques to manage our environment as efficiently and effectively as possible.

The work of the Environment Agency's Science Group is a key ingredient in the partnership between research, policy and operations that enables the Environment Agency to protect and restore our environment.

The science programme focuses on five main areas of activity:

- **Setting the agenda**, by identifying where strategic science can inform our evidence-based policies, advisory and regulatory roles;
- **Funding science**, by supporting programmes, projects and people in response to long-term strategic needs, medium-term policy priorities and shorter-term operational requirements;
- **Managing science**, by ensuring that our programmes and projects are fit for purpose and executed according to international scientific standards;
- **Carrying out science**, by undertaking research – either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available to our policy and operations staff.

Steve Killeen

Head of Science

Executive summary

The Environment Agency authorises the discharges of radioactive wastes as liquids and/or gases from nuclear sites in England and Wales under the Radioactive Substances Act 1993. The Environment Agency requires the nuclear industry to undertake environmental radiological monitoring around its sites and, in addition, it has responsibility for undertaking its own programme as an independent check.

The aim of this project was to identify, and provide guidance on, best practice techniques for these monitoring programmes. These techniques encompass the instrumental monitoring of contamination and dose rates as well as the collection and preparation of food, indicator and air/deposition samples. The criteria used in our selection of techniques were that they should enable the monitoring programme to be efficient and cost-effective, and make use of the best available scientific methods.

The work carried out for this study included:

- reviewing the literature on guidance and standards on sample collection protocols and radiological monitoring of the environment;
- identifying best practice techniques for individual environmental media and monitoring tasks;
- preparing guidance notes to implement these techniques.

The preparation of guidance notes was critically reviewed during a one-day workshop attended by a key group of experts involved in UK radiological monitoring. As well as enabling the Centre for Environment, Fisheries and Aquaculture Science and the Environment Agency to incorporate the views of these stakeholders, the workshop helped to disseminate the information arising from this project.

Guidance notes are listed in the tables contained in this report.

Contents

1 Introduction

The Environment Agency authorises the discharge of radioactive wastes as liquids and/or gases from nuclear sites in England and Wales under the Radioactive Substances Act 1993. The Environment Agency, therefore, requires the nuclear industry to undertake environmental radiological monitoring around its sites to:

- assess the dose to the critical group and enable this dose to be compared to the dose limit for members of the public;
- understand the impact of discharges on the environment, such as identifying mechanisms and locations where radionuclides re-concentrate, and monitor trends of environmental impact;
- confirm the validity of reported discharges by comparing measured concentrations to anticipated concentrations;
- confirm the validity of modelling of discharges.

The Environment Agency considers it necessary to place clear requirements on nuclear site operators as to the techniques that should be used to monitor the environment.

The Environment Agency is also responsible for undertaking its own programme of environmental radiological monitoring around nuclear sites and at more remote locations. This is used to provide an independent check on monitoring undertaken by nuclear operators around their sites, and to check on the impact of radioactive waste discharges on the environment. The Department for Environment, Food and Rural Affairs (Defra) reports the results of the air, rain and drinking water monitoring of remote locations to the EU under Article 36 of the Euratom treaty.

The goals of this project were to:

- identify the different techniques adopted for monitoring radioactivity in the environment;
- select the best methods to use in future programmes.

The criteria used to select the optimum techniques were to combine the best scientific methods with efficient and cost-effective monitoring.

The specific aims of this project were to identify best practice techniques and provide guidance on their implementation for:

- contamination monitoring of beaches and coastal areas, where contamination may be in the form of a few discrete particles or reasonably homogenous and widely dispersed;
- dose rate monitoring above coastal sediments, freshwater sediments and soil;
- collection and preparation of marine or freshwater samples (such as sediment, seawater, seaweed, fish and shellfish);
- collection and preparation of terrestrial samples (soil, grass, milk, meat, vegetables, fruit);
- collection and preparation of air and deposition samples (such as ambient air, passive shades, dry/wet/total deposition, road drain sediments, house dust).

This study was partly spurred by the recent submission of a questionnaire to Member States from the European Commission requesting information on radiological monitoring of effluent and the environment around nuclear sites in relation to Article 35

of the Euratom treaty. This study will thus assist the Environment Agency in its preparations to link into the EC project.

The key audience for this report includes nuclear regulators and monitoring programme managers within the Environment Agency, nuclear industry and radiological monitoring contractors. Other interested organisations include the Scottish Environmental Protection Agency, the Health Protection Agency Radiation Protection Division (formerly the National Radiological Protection Board) and the Food Standards Agency. The Centre for Environment, Fisheries and Aquaculture Science (Cefas) also has a direct interest in this work because of its role in providing independent advice on all aspects of radiological protection. Cefas has recently submitted a tender to address the requirements of the European Commission for providing an overview of national environmental monitoring requirements and inspection activities with regards to nuclear installations by member states (Tender No. TREN/H4/47-2004). This study represents an essential next step in development of the Commission's programme of verification under Article 35 of the Euratom Treaty.

2 Methods

In order to identify best practice techniques, the work programme was divided into a number of different tasks described below.

2.1 Task 1: Literature review

Review the literature on guidance and standards on radiological monitoring and sampling of the environment

As agreed at the outset of this project, the review was divided into two subtasks:

1.1 A full literature search to obtain published literature on guidance and standards on radiological monitoring and sampling of the environment. The Environment Agency also highlighted particular documents (in the tender) to be included in the review.

1.2 For each reference source, an outline of the scope of the guidance and its status provided in a tabular format. Tables to cross-reference the literature sources to each monitoring or sampling type. The sample types and environmental media that were considered are shown in Table 1.

2.2 Tasks 2 and 3: Identify best practice and prepare guidance

Following the completion of Task 1 and discussion at the subsequent progress meeting, Tasks 2 and 3 were carried out concurrently to identify the best methods for each of the sampling and monitoring types using the criteria below.

Identify best practice techniques for radiological monitoring and sampling of the environment

2.1 Identify and describe best practice techniques for monitoring, sample collection, sample storage, sample preservation and sample preparation for different environmental media/sample types. Those, which should be included as a minimum, according to the tender specification are shown in Table 1. Potentially more than one technique for each environmental media/sample type was identified.

2.2 Particular attention to identifying novel techniques that could improve the efficiency of monitoring.

2.3 Where more than one suitable technique is found, provide an assessment of the costs, risks and benefits of each option. Quantify the potential efficiency gain (in unit terms as necessary).

2.4 Consult with experts and practitioners where necessary to ensure that the most suitable techniques are identified. The Environment Agency provided a list of suitable persons to contact. This list was supplemented by the contractor's contacts.

2.5 Prepare a report containing the outputs of Tasks 1 and 2 to provide the rationale for the selection of best practice techniques.

Prepare guidance for environmental radiological monitoring

3.1 Use the results of Tasks 1 and 2 to prepare detailed guidance on implementing monitoring/sampling techniques for different environmental media/sample types.

3.2 Produce this guidance report as a user-focused document giving clear step-by-step guidance on how to implement monitoring/sampling techniques.

2.3 Task 4: Workshop to review guidance

Review the guidance documents produced in earlier tasks in a one-day workshop. At the outset (with agreement of the Environment Agency), it was envisaged that the workshop would allow a range of experts to scrutinise the findings and information reported in the guidance tables. The workshop would therefore enable Cefas and the Environment Agency to incorporate the views of these stakeholders, and enable a consensus of best practice techniques to be established for radiological monitoring and sampling in the environment.

3. Results and observations

3.1 Task 1: Literature review

Task 1.1

A thorough literature review was undertaken to obtain published literature on guidance and standards on radiological monitoring and sampling of the environment. At the outset, the sample types and environmental media that were considered are shown in Table 1 for terrestrial and inter-tidal monitoring.

Three separate computer searches were carried out as listed below, along with a review of the published information provided by the Environment Agency:

- ASFA (Aquatic Sciences and Fisheries Abstracts - http://www.csa.com/aboutcsa/company.php)
- DIALOGWEB (http://www.dialog.com/products/dialogweb/)
- SCORPUS (http://www.utwente.nl/ub/)

A number of keywords for each of the sampling/monitoring types were used, applicable to the field of radioactivity. Each search produced a large number of references. Abstracts of all the individual references were reviewed for their applicability to the project and full copies of the manuscripts were obtained for those considered appropriate to this study. A few outstanding manuscripts on the Environment Agency's list were also obtained (including documents in draft and international/national standard documents).

The vast majority of results from the literature search were **not** applicable to this project for the following reasons:

- a 'matter of fact' description without reference to other standards or guidelines;
- location specific - a brief commentary, for example with respect to specific waste disposal locations/studies in the USA;
- a comparison of two or more techniques without a positive outcome;
- a brief commentary for the purpose of the development of a radioanalytical method;
- a brief commentary for the purpose of research (an investigation of mechanistic behaviour, spatial/temporal distributions and so on).

A good example is provided by the work of Isaksson (2002) who compared sampling methods for pasture, soil and deposition for radioactivity emergency preparedness in Nordic countries. The driver for this study was similar to that of the present investigation, in that the Nordic countries have several different organisations and authorities involved in sampling and measurements of radioactivity. It is therefore important that their results are comparable and not influenced by differences in the sampling procedure. The 2002 study found that a range of methods was used to collect herbage, soil, and deposition samples. For example, the height at which grass was cut varied from one cm to five cm above the ground, whilst soil samples were collected using a variety of corers to a range of depths. Unfortunately, the study was unable to recommend a standard sampling procedure for all three materials. Instead, it was concluded that although the methods used were variable, in the event of an

emergency the use of standardised methods might actually worsen the results, particularly if not previously implemented in routine programmes.

Communication with other laboratories, Institut de Radioprotection et de Suret Nuclaire (IRSN) (France) and Radiological Protection Institute of Ireland (RPII) (Ireland), who undertake regular monitoring for their respective countries, suggests that in-house written procedures (not published) are based on past experience. There is no expectation that either institution is likely to change their approach, either in the short or medium term.

Task 1.2

Table 2 lists the results of the review of published literature for guidance and standards on radiological monitoring and sampling of the environment. A number of international standard methods and guidelines have been added or updated from those provided by the Environment Agency. Where the standard method/guideline does not relate to radioactivity but is applicable, this has been noted in the table for future reference. Standard methods/guidelines were obtained for the majority of sample/monitoring types. The sample/monitoring types lacking in references include contamination monitoring (C4), seaweed (C7), fish (C8) and shellfish (C9) for coastal environments. Only a generic reference is provided for agricultural food products (T7-T10 inclusive), although there is a wealth of international standard methods available for non-radioactive purposes.

An additional literature search was undertaken to assess whether further references not specific to radioactivity might be applicable to the requirements of this project. The following sample/monitoring types were considered: fruit and vegetables (T7), meat and meat products (T8), game (T9), honey (T9), eggs (T9), cereal (T10), seaweed (C7), fish (C8) and shellfish (C9). A few references were found for fish (C8) and shellfish (C9), which could be used in the context of radioactivity. References for guidance on fruit and vegetables (T7), cereal (T10) and seaweed (C7) are also listed, although the information provided is not as comprehensive as for other sample types. References were not found for meat and meat products (T8), game, honey and eggs (T9). The outcome from this search was incorporated into Table 2. Codes for the different sampling/monitoring types are provided in Table 1.

The references in Table 2 indicate that, despite a plethora of publications providing sampling and preparation information for the majority of sample types, specific guidance on some materials was not forthcoming (such as seaweed). Upon request by the Environment Agency, the appropriate papers were reviewed to determine if guidance could be extracted from the body of published information. The outcome of the review for seaweed sampling is given in the paragraph below. In summary however, it was not possible to use this information to provide generic sampling and collection details from these papers.

Recommended field sampling methods for seaweed has been published for applied biologists faced with the problem of measuring macrophyte response to environmental change (Raschke and Rusanowski, 1984). At present, however, there is no standard method or widely accepted protocol for the collection and preparation of seaweed tissue for use in biomonitoring studies (Gledhill *et al*., 1998), including radioactivity in the marine environment. A series of problems have been identified (Phillips, 1994) including i) species identification; ii) availability of the same species throughout the year at all sites; iii) variable bioaccumulation between individual species; iv) temporal variations in growth rate, hence contaminant accumulation in old and young thallus; v) contamination from adherent particles. Although a large number of publications provide data on contaminant accumulation in seaweeds, the applicability of the

information in deriving a standard protocol is often severely restricted and of local importance only (see Ahn *et al*., 2004). The typical conclusion drawn from these studies is that the results suggest the potential utility of species x, y and z as biomonitors for pollution monitoring in a particular area. Best practice to minimise the first four problems is to select common algal species that are easy to identify (such as *Fucus serratus* or *F. vesiculosis*) and to collect non-reproductive tissue from similar sized plants at the same season and tidal level (Gledhill *et al*., 1998). For practical reasons, it is impossible to restrict collection for a nationwide programme to just one or even two species, as abundance varies significantly between sites and seasons in response to environmental conditions such as wave exposure and sedimentation (Díez *et al*., 2003) and stochastic history (Sapper and Murray, 2003). A systematic solution to the fifth problem has yet to be widely accepted. Thus, individual laboratories adopt different (often unpublished) procedures in an attempt to eliminate as many of variables as possible, based on their past experience and local knowledge of conditions at the sampling sites.

3.2 Tasks 2 and 3: Identify best practice and prepare guidance

Critical evaluation of the references identified in the literature review revealed that:

- the majority of references are quite generic;
- although they provide important background, the references do not offer sufficient detail nor provide scientific validation (for example, by experimental evidence) to enable step-by-step instruction to be cited in the style of a standard operating procedure (SOP);
- protocols were not necessarily developed or described for the specific objectives required for this study.

Therefore, because of the lack of precise information for some sample/monitoring types, if the guidance was taken solely from one reference, then the outcome could provide information that might be:

- unrealistic for all sampling situations for any given sample/monitoring type and objective;
- potentially contradictory to currently undertaken protocols for the sample/monitoring types and objectives required;
- indefensible or unacceptable to the wider scientific community.

In response to these observations, with the agreement of the Environment Agency the initial approach for this project was adapted to produce sufficiently detailed information based on expert knowledge and interpretation of the available information. In essence, this involved preparing detailed information for each sampling or monitoring type to best summarise the techniques, by highlighting the important aspects of sampling and preparation methods.

Inevitably, some sampling and collection procedures may depend upon the requirement of specific types of radiometric/radiochemical analysis. For example, the measurement of organically bound tritium (OBT) generally requires a lower oven temperature (less than 60^0 C) to dry the sample, to minimise the loss of volatile components. It is therefore assumed that, for the purpose of the information provided here (unless otherwise stated), the descriptions refer to standard radiometric/radiochemistry analyses (such as gamma spectrometry).

Having taken this deviation in approach, initial guidance was produced on each of the sampling/monitoring types for open discussion between Cefas and the Environment Agency. Recommendations were discussed and information shared by email between the two organisations over a series of weeks. Following a number of revisions, a draft guidance document was produced for review by the workshop participants who could appraise for accuracy, appropriateness, omissions and so on, and from which a final document could be produced.

The potential costs, together with the risks/weaknesses and benefits/strengths of alternative monitoring methods were identified, where these approaches were distinctly different (for example, in situ gamma spectrometry compared to sediment and soil coring). A workshop draft was prepared for critical evaluation and is provided in Table A1 in Appendix A.

A summary of the workshop draft on best practice monitoring guidance is given in Table A2 in Appendix A for terrestrial and inter-tidal monitoring. For the purpose of the workshop, the techniques were subdivided into three groups (terrestrial non-food sample, terrestrial food sample and inter-tidal sample).

3.3 Task 4: Workshop

A full report of the workshop, held at Defra, Ashdown House on 8th February 2006, is provided in Appendix B.

The workshop was well attended by a variety of experts, including the nuclear industry, regulators, monitoring contractors and other users. Their suggestions and comments were wide-ranging and extremely useful. The comments were captured and, as far as possible, have been recorded in the notes of the workshop report. Participants' willingness to support the event and their contribution is acknowledged with thanks. We would also like to acknowledge the support of Defra and their staff in hosting the workshop.

4. Conclusions

The final outcome of this project, an analysis of alternative techniques and best practice environmental monitoring guidance, is given in Tables 3 and 4. Health and safety considerations have not been included in the final guidance provided.

The importance of defining sampling and monitoring objectives was acknowledged at the workshop. The final outcome thus includes more defined objectives than the previous workshop draft and the guidance has been updated to reflect these changes.

A wide range of opinions was expressed at the workshop and, as far as possible, these have been taken in to account in the final version of the guidance.

Given that different judgements are inherent in this type of work, it is acknowledged that the term ‘best practice’ may not be universally appropriate. Nevertheless, this report represents the collective opinions of those who have been involved in the process.

5. Recommendations

Although guidance was successfully produced for most sample types, some issues were not fully resolved. If possible, the following issues should be considered further:

1. Health and safety considerations have not been included in the final guidance in this report. However, it is recognised that all aspects of sampling and monitoring should take health and safety into account to maintain appropriate working conditions, equipment and systems of work for all personnel. As well as general health and safety issues concerning field studies, it will be necessary to consider procedures that have a defined risk (such as handling of sewage material) and to provide specific risk assessments (and training) for these procedures.
2. Procedures should be defined for the appropriate action to be taken if a 'hot particle' is found. These will need to address health and safety requirements, but also the responsibility for custody and detailed analytical requirements.
3. The representative sample performance should be defined to indicate the appropriate number of samples to be taken (for example, sampling uncertainty to be less than 50 per cent).
4. The representative sub-sample performance should be defined to indicate the appropriate number of sub-samples to be taken (for example, sub-sampling uncertainty to be less than 10 per cent).
5. The representative batch sample performance should be defined to indicate the appropriateness of batch, or individual samples, used for analysis.
6. There is a requirement to define performance criteria for dose rate and contamination monitoring instruments, including defined detection limits.
7. There is a requirement to define a performance criterion for the uncertainty in the measurement of airflow for High/Medium Volume Air Sampling (HVAS/MVAS).

References

In the main report:

Ahn, I.Y., Choi, H.J., Ji, J., Chung, H. and Kim, J.H., 2004. Metal concentrations in some brown seaweeds from Kongsfjorden on Spitsbergen, Svalbard Islands. *Ocean and Polar Research*, 26 (2), 121-132.

Diez, I., Santolaria, A., Gorostiaga, J.M., 2003. The relationship of environmental factors to the structure and distribution of sub-tidal seaweed vegetation of the western Basque coast (N Spain). *Estuarine, Coastal and Shelf Science*, 56 (5-6), 1041-1054.

Gledhill, M., Brown, M.T., Nimmo, M., Moate, R. and Hill, S.J., 1998. Comparison of techniques for the removal of particulate material from seaweed tissue. *Marine Environmental Research*, 45 (3), 295-307.

Isaksson, M., 2002. Sampling methods for pasture, soil and deposition for radioactivity emergency preparedness in the Nordic countries. *Boreal Environment Research*, 7, 113-120.

Phillips, D.J.H., 1994. Macrophytes as biomonitors of trace metals. In: Kramer, K.J.M. (Editor). *Biomonitoring of Coastal Waters and Estuaries*, CRC Press, Florida.

Raschke, R.L. and Rusanowski, P.C., 1984. Aquatic macrophyton field collection methods and laboratory analyses. In: W.M. Dennis and W.G. Isom (eds.). *Ecological assessment of macrophyton: collection, use, and meaning of data*. American Society for Testing and Materials Special Publication 843. Philadelphia, PA.16-27.

Sapper, S.A. and Murray, S.N., 2003. Variation in structure of the sub-canopy assemblage associated with southern California populations of the inter-tidal rockweed *Silvetia compressa* (Fucales). *Pacific Science*, 57 (4), 433-462.

In Table 4:

1. *Environment Agency work instruction protocol for groundwater quality sampling* (ES006), Environment Agency Management System (AMS) 275_04 ES006.

2. *Guidance on the monitoring of landfill, leachate groundwater and surface water*, R&D project HOCO_232.

3. ISO 5667 Part 11, *Water quality sampling – Guidance on sampling groundwaters*.

4. ISO 5667 Part 18, *Water quality sampling – Guidance on sampling groundwater from contaminated sites*.

5. *Methodology for monitoring and sampling groundwater*, National Rivers Authority R&D Note 126.

6. *Technical guidance note (Monitoring) M5: Routine measurement of gamma air kerma rate in the environment*. Her Majesty's Stationery Office (HMSO), 1995.

7. Daish, S.R., Dale A.A., Dale, C.J., May, R. and Rowe, J.E., 2005. The temporal variations of ^{7}Be, ^{210}Pb and ^{210}Po in air in England. *Journal of Environmental Radioactivity,* 84, 457-467.

8. Mudge, S.M., Assinder, D.J. and Russell, A.T. *Meso-scale variation of radionuclides in sediments and implications for sampling*. R&D Technical Report (P3-093/TR) and Project Record (P3-0937/TR). (In draft).

9. Wood, M.D., Copplestone, D. and Crook, P*. UK soil and herbage pollutant survey UKSHS Report 2: Chemical and radiometric sample collection methods.* R&D Technical Report (P3-083). (In draft)

10. Copplestone, D., Wood, M.D., Tyler, A. and Crook, P. *UK soil and herbage pollutant survey UKSHS Report 4: Soil property and radiometric analytical methods*. R&D Technical Report (P3-083) (In draft).

11. Mudge, S.M., Assinder, D.J. and Russell, A.T., 2001. *Micro-scale variability in contaminants in surface sediments*. R&D Technical Report (P3-057/TR) and Project Record (P3-057/TR). Environment Agency December 2001.

12. Baker, A.C., Darwin, C.J., Jefferies, N.L., Towler, P.A. and Wade, D.L., 2000. *Best practice guidance for site characterisation. A report from the Safeguards Learning Network. Managing contaminated land on nuclear licensed and defence sites*. The Construction Industry Research & Information Association (CIRIA) Publication W001.01.

13. *Radon in water sampling program*. Environmental Protection Agency/Eastern Environmental Radiation Facility (EPA/EERF)-Manual-78-1 (1978).

14. Special issue of *Journal of Radiological Protection*. Conference proceedings, *Managing historic hot particle liabilities in the marine environment 2*, Nairn, Scotland. 30th August to 31st August 2005. (In preparation).

15. *An international comparison of airborne and ground-based gamma ray spectrometry*. Results of the ECCOMAGS 2002 Exercise, 24th May to 4th June 2002, Dumfries and Galloway, Scotland (Eds: D.C.W. Sanderson *et al*,), Scottish Universities Environment Research Centre, ISBN 0 85261 783 6 (2003).

List of abbreviations

APS:	Air passive shades
AWE:	Atomic Weapons Establishment
BGS:	British Geological Survey
BNGSL:	British Nuclear Group Sellafield Ltd
CEAR:	Canadian Environmental Assessment Registry
CEFAS:	Centre for Environment, Fisheries and Aquaculture Science
CEH:	Centre for Ecology and Hydrology
DQO:	Data quality objective
Defra:	Department for Environment, Food and Rural Affairs
EC:	European Commission
EA:	Environment Agency
EC:	European Commission
EU:	European Union
Euratom:	European Atomic Energy Community
FSA:	Food Standards Agency
H_2O_2:	Hydrogen peroxide
HPA:	Health Protection Agency
HVAS/MVAS:	High Volume Air Sampling/Medium Volume Air Sampling
IAEA:	International Atomic Energy Agency
IRSN:	Institut de Radioprotection et de Suret Nuclaire
LGC:	Laboratory of the Government Chemist
MARLAP:	Multi-Agency Radiological Laboratory Analytical Protocols
NIRAS:	NNC Independent Radiation Assessment Services
NPL:	National Physical Laboratory
R&D:	Research and development
RPII:	Radiological Protection Institute of Ireland
SEPA:	Scottish Environment Protection Agency
SUERC:	Scottish Universities Environmental Research Centre
TLD:	Thermoluminescent dosimeter
US EPA:	United States Environmental Protection Agency
US MARSSIM:	United States Multi-Agency Radiation Survey and Site Investigation Manual

Tables

Table 1: Sample/monitoring types

Environment	Sample/monitoring type	Sample/monitoring type code
Terrestrial	Terrestrial dose rate monitoring	T1
	Air passive shades and HVAS/MVAS	T2
	Wet, dry, total deposition	T3
	Grass/herbage	T4
	Soil	T5
	Milk	T6
	Fruit and vegetables	T7
	Meat and products	T8
	Eggs, honey and game	T9
	Cereal	T10
	Freshwater (surface)	T11
	Groundwater	T12
	Drinking water	T13
	Freshwater sediments	T14
	Leachate	T15
	Sewage/sludges	T16
	Road drain sediments	T17
	Contaminated land	T18
	Wildlife	T19
	Aerial gamma surveys	T20
	Waste water	T21
Inter-tidal	Estuary/coastal dose rate monitoring	C1
	Estuary/coastal contamination monitoring – general contamination	C2
	Estuary/coastal contamination monitoring – small particles	C3
	Contamination monitoring – fishing gear and so on	C4
	Seawater	C5
	Estuary/coastal sediments	C6
	Seaweed	C7
	Fish	C8
	Shellfish (mollusc/crustacean)	C9

Table 2: Guidance and standards for radiological monitoring and sampling of the environment

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Measurement of radioactivity in the environment. Soil - Part 1. General guide and definitions. BS ISO18589-1:2005(E)	Contains general requirements (guidelines, definitions, including sampling) for radio-assay on soil samples.	Standard (International)	T5	Recent update of ISO 18589-1, BS18589 being updated.
Measurement of radioactivity in the environment. Soil - Part 2. Method for the selection of sampling strategy, sampling and pre-treatment of samples. ISO/DIS 18589-2 (in preparation)	Contains information on different approaches or sampling strategies, ensuring sample is representative of soil type. Includes information on storage and pre-treatment to ensure physical-chemical characteristics are constant over time.	Standard (International)	T5	Document under preparation.
Soil quality. Sampling - Part 1. Guidance on design of sampling programmes. BSISO 10381-1:2002	Contains general principles to be applied in the design of sampling programmes for the purpose of characterising and controlling soil quality and identifying sources and effects of contamination of soil and related material.	Standard (International)	T5, T12	BSISO 18381 not specific to radioactivity
Soil quality. Sampling - Part 2. Guidance on sampling techniques. BSISO10381-2: 2002	Contains guidance on techniques for taking and storing soil samples. Provides information on typical equipment to enable specific sampling procedures to be carried out and representative samples to be collected. Guidance is given for use to enable both disturbed and undisturbed samples to be taken at different depths.	Standard (International)	T5, T12	
Soil quality. Sampling - Part 3. Guidance on safety. BSISO 10381-3:2001	Contains information on personal protection, protection of buildings and installations, and protection of the environment.	Standard (International)	T5	
Soil quality. Sampling - Part 4. Guidance on the procedure for investigation of natural, near-natural and cultivated sites ISO 10381-4:2003	Contains information on the sampling of soils from areas used for agriculture, horticulture and special crop-cultivation. It sets out appropriate strategies for the design of sampling programmes, field procedures and subsequent treatment of samples for transport and storage prior to sample pre-treatment (such as drying, milling).	Standard (International)	T5	

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Soil quality. Sampling - Part 5. Guidance on the procedure for the investigation of urban and industrial sites with regard to soil contamination. ISO 10381-5:2005	Provides guidance on the procedure for the investigation of urban and industrial sites, where either it is known that soil contamination is present, or the presence of soil contamination is suspected. It is used to establish the contamination status of a site, or to establish the environmental quality of a site for other purposes.	Standard (International)	T5, T18	
Soil quality. Pre-treatment of samples by freeze-drying for subsequent analysis. ISO 16720:2005	Specifies a method for pre-treatment of soil samples by freeze-drying for subsequent analysis. It is applicable to soil samples for subsequent determination of elements recognised as non-volatile under freeze-drying conditions, and can also be applied to samples from other sediments.	Standard (International)	T5, T14, T16, T17, C6	
Milk and milk products. Guidance on sampling. BS ISO 707:1977	Provides guidance on methods of sampling milk and milk products. Includes information on sampling equipment and preservation, storage and transport of samples.	Standard (International)	T6	BS ISO being updated - not specific to radioactivity
Water quality sampling - Part 1. Guidance on design of sampling programmes. BS6068-6.1:1981, ISO5667-1:1980, BSEN25667-1:1994	Sets out the general principles to be applied for the purposes of quality control, quality characterisation, and identification of sources of pollution of water, including bottom deposits and sludges.	Standard (International)	T11, T12, T13, T15, C5	BS6068-6.1;1981 ISO5667-1:1980 being updated
Water quality sampling - Part 2: Guidance on sampling techniques. BS6068-6.2:1991, ISO5667-2:1991, BSEN25667-2:1993	Provides guidance for techniques used to obtain the data necessary to make analyses for the purposes of quality control, quality characterisation and identification of sources of pollution of waters.	Standard (International)	T11, T12, T13, T15, C5	Does not include detailed instructions for specific sampling situations

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Water quality sampling - Part 3: Guidance on the preservation and handling of water samples. BS6068-6.3: 2003, ISO 5667-3:2003 BSENISO5667-3: 2003	Provides general guidelines on the precautions to be taken to preserve and transport all water samples including those for biological analyses, but not those intended for microbiological analysis. These guidelines are particularly appropriate when spot or composite samples cannot be analysed on-site and have to be transported to a laboratory for analysis.	Standard (International)	T11, T12, T13, T15, C5	Provides detailed instructions for specific determinands
Water quality sampling - Part 6: Sampling. Section 6.4. Guidance on sampling from lakes, natural and man-made. BS6068-6.4: 1987, ISO5667-4: 1987	Presents detailed principles to be applied to the design of programmes, techniques and the handling and preservation of samples of water. The main objectives are measurements of quality characterisation, of quality control and for specific reasons (specific phenomena such as fish mortality). Microbiological examinations are not included.	Standard (International)	T11	
Water quality sampling - Part 6: Sampling. Section 6.5. Guidance on sampling drinking water and water used for food and beverage processing. BS6068-6.5: 1991, ISO5667-5: 1991	Provides guidance on design of sampling programmes, sampling techniques and the handling and preservation of samples. Includes the sampling of water in a treatment plant and the distribution system.	Standard (International)	T13	BS6068-6.5: 1991, ISO5667-5: 1991 being updated
Water quality sampling - Part 6: Sampling. Section 6.6. Guidance on sampling of rivers and streams. BS6068-6.6: 1991, ISO5667-6: 1990	Sets out the principles to be applied to the design of sampling programmes, sampling techniques and the handling of water samples from rivers and streams for physical and chemical assessment.	Standard (International)	T11	BS6068-6.6: 1991, ISO5667-6: 1990 being updated

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Water quality sampling - Part 6: Sampling. Section 6.8. Guidance on sampling wet deposition. BS6068-6.8: 1993, ISO5667-8: 1993	Provides guidance on the design of sampling programmes and the choice of instrumentation and techniques for the sampling of the quality (main components) of wet deposition. Does not cover measurement of the quantity of rain, dry deposition or other types of wet deposition such as mist, fog and cloud waters. The main objectives are control of local emissions and assessment of long range transport of airborne pollutants.	Standard (International)	T3	
Water quality sampling - Part 6: Sampling. Section 6.9. Guidance on sampling of marine waters. BS6068-6.9: 1993, ISO5667-9: 1992	Provides guidance on the principles to be applied to the design of sampling programmes, sampling techniques and the handling and preservation of samples of sea water from tidal waters.	Standard (International)	C5	
Water quality sampling - Part 6: Sampling. Section 6.10. Guidance on sampling of waste waters. BS6068-6.10: 1993, ISO5667-10: 1992	Contains details on the sampling of domestic and industrial wastewater, the design of sampling programmes and techniques for collection of samples including safety aspects. Covers waste water in all its forms. Sampling of accidental spillages is not included, although the methods described in certain cases may also be applicable to spillages.	Standard (International)	T21	
Water quality sampling - Part 6: Sampling. Section 6.11. Guidance on sampling of ground waters. BS6068-6.11: 1993, ISO5667-11: 1993	Provides guidance on the design of sampling programmes, sampling techniques and the handling of water samples taken from groundwater for physical, chemical and microbiological assessment. The general purpose of sampling programmes for groundwaters is to survey the quality of groundwater supplies, to detect and assess groundwater pollution, to assist in groundwater resource management, and other more detailed objectives.	Standard (International)	T12	

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Water quality sampling - Part 6: Sampling. Section 6.12. Guidance on sampling of bottom sediments. BS6068-6.12: 1996, ISO5667-12:1995	Provides guidance on the sampling of sediments from rivers, streams, lakes and similar standing waters and estuaries. Sampling of industrial and sewage work sludges and ocean sediments are excluded.	Standard (International)	T14	
Water quality sampling - Part 6: Sampling. Section 6.13. Guidance on sampling of sludges from sewage and waste water treatment plants. BS6068-6.13: 1998, ISO5667-13:1998	Provides guidance on sampling of sludges from sewage and water treatment works and industrial processes. It is applicable to all types of sludge.	Standard (International)	T16	
Water quality sampling - Part 6: Sampling. Section 6.14. Guidance on quality assurance of environmental water sampling and handling. BS6068-6.14: 1998, ISO5667-14: 1998	Provides guidance on the selection and use of various quality assurance techniques related to the manual sampling of surface, potable, waste, marine and ground waters.	Standard (International)	T11, T12, T13, C5	
Water quality sampling - Part 6: Sampling. Section 6.15. Guidance on the preservation and handling of sludge and sediment samples. BS6068-6.15: 1999, ISO5667-15:1999	Provides guidance on preservation and handling of sludge and sediment samples.	Standard (International)	T14, T16	BS6068-6.15: 1999, ISO5667-15:1999 being updated
Water quality sampling - Part 6: Sampling. Section 6.17. Guidance on sampling of suspended sediments. BS6068-6.17: 2000, ISO5667-17:2000	Provides guidance that is applicable to the sampling of suspended solids for the purpose of monitoring freshwater and particularly flowing freshwater systems (rivers and streams). Certain elements may be applicable to freshwater lakes and reservoirs.	Standard (International)	T14	BS6068-6.17: 2000, ISO5667-17:2000 being updated
Water quality sampling - Part 6: Sampling. Section 6.18. Guidance on sampling of groundwater at contaminated sites. BS6068-6.18: 2001, ISO5667-18:2001	Provides guidance on the sampling of groundwater at potentially contaminated sites. It is applicable where contamination of the subsurface could exist as a result of downward migration of contaminants.	Standard (International)	T12	

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Water quality sampling - Part 19: Guidance on sampling of marine sediments. BS EN ISO 5667-19:2004, BS 6068-6.19:2004	Provides guidance for the sampling of sediments in marine areas for analysis of their physical and chemical properties for monitoring purposes and environmental assessments. It encompasses sampling strategy, requirements for sampling devices, observations made and information obtained during sampling, handling, and packaging and storage of sediment samples.	Standard (International)	C6	
Agricultural food products - Layout for a standard method of sampling from a lot. ISO 7002:1986	General rules for drafting standard methods; they cannot be used for sampling products. Rules for drafting individual aspects, such as title, introduction, scope, field of application, references, definitions, principles, administrative arrangements, sampling equipment, procedures, packing, sealing and marking, precautions during storage and transportation of samples, sampling report.	Standard (International)	T7, T8, T9, T10	Food products in general
Investigation of potentially contaminated sites. Code of practice. BS10175: 2001	Provides guidance on, and recommendations for, the investigation of potentially contaminated land to determine or manage risks. It includes setting objectives of an investigation, setting a strategy, and designing the different phases for the investigation, sampling and on-site testing, laboratory analysis and reporting.	Standard (British)	T18	
Technical guidance note (Monitoring) M5: Routine measurement of gamma air kerma rate in the environment. HMSO, 1995.	Provides guidance on the routine measurement of gamma ray air kerma in the environment. It includes protocol for the measurement, interpretation and reporting of measurements. Techniques, instruments and calibration facilities are reviewed.	Guidance	T1,C1	

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Environmental monitoring strategy - Ambient air M8. Environment Agency, 2000	Provides guidance on developing monitoring strategies for assessing levels of pollutants in the ambient atmosphere. Initial consideration is given to identifying the aims of an ambient air quality monitoring study and the importance of developing a monitoring strategy to ensure these objectives are met.	Guidance	T2	Not specific to radioactivity
Monitoring methods for ambient air M9. Environment Agency, 2000	Provides guidance on the monitoring methods available for assessing levels of pollutants in the ambient atmosphere. Initial consideration is given to the regulatory framework and to identifying the aims of an ambient air quality monitoring study. The different generic sampling and analysis techniques used in ambient air quality monitoring are reviewed, before focusing on the different methods available for each pollutant (including particulate pollutants and gaseous pollutants).	Guidance	T2	Not specific to radioactivity
Monitoring of radioactive release to atmosphere from nuclear facilities M11. Environment Agency, 1999	Provides guidance on the monitoring of radioactive releases to atmosphere from nuclear facilities. The equipment used for monitoring and the way the equipment is used is described.	Guidance	T2	
Monitoring of radioactive releases to water from nuclear facilities M12. Environment Agency, 1999	Provides guidance on the monitoring of radioactive releases to water from nuclear facilities. The equipment used for monitoring and the way the equipment is used is described.	Guidance	T21	
Monitoring of particulate matter in ambient air around waste facilities M17. Environment Agency, 2004	Provides information on the monitoring methods and techniques available for quantitatively assessing levels of particulate matter in ambient air around waste facilities.	Guidance	T3	Not specific to radioactivity
Monitoring of discharges to water and sewage M18. Environment Agency, 2004	Provides guidance to monitoring contractors, industry and other parties interested in the monitoring of discharges to water	Guidance	T21	Not specific to radioactivity

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
A review of methods for sampling large airborne particles and associated radioactivity. K.W. Nicholson & J.A. Garland, DOE/RW/90/016. Jan 1990	Provides a review of techniques to measure and assess the dispersion of airborne radionuclides in ambient air.	Guidance	T2	
Techniques for measuring airborne radionuclides: Current practice and research requirements in the UK. DETR/RADREM/97.001.	Provides a review of techniques to measure and assess the dispersion of airborne radionuclides in ambient air, including methods for continuous monitoring and occasional measurement.	Guidance	T2	
Evaluation of standards for the sampling, preparation and measurement of radioactivity levels in soils. Ken Nicholson, AEA Technology Issue 2, October 2002.	Provides information from EU Member States on their soil sampling techniques and provides recommendations for standardisation of techniques used for sampling, preparation and measurement of radioactivity in soils.	Guidance	T5	
National sampling procedures manual volume 025. Quality management system for environmental sampling. J. Adam. Environment Agency, April 1998	Provides recommended procedures for sampling and work instructions in the field for discharge and environmental samples.	Guidance	T14, T15	
Technical support material for the regulation of radioactively contaminated land. Entec UK Ltd and NRPB. R&D Technical Report P307. Environment Agency, Bristol, 1999.	Provides a review of field and laboratory methods, considering both direct monitoring and conventional sampling (and analysis) for other methods.	Guidance	T18	
UK soil and herbage pollutants survey UKSHS Report 2: Chemical and radiometric sample collection methods. R&D Technical Report (P3-083). Wood, M.D., Copplestone, D. and Crook, P. (draft)	Provides protocols for the collection of soil and herbage samples for soil property, chemical and radiometric analysis	Guidance	T1, T4, T5	
UK soil and herbage pollutants survey UKSHS Report 4: Soil property and radiometric analytical methods. R&D Technical Report (P3-083) Copplestone, D., Wood, M.D., Tyler, A. and Crook, P. (draft)	Provides details for the soil property and radiometric analytical methods, both field and laboratory, including air kerma, in situ gamma spectrometry and laboratory gamma spectrometry.	Guidance	T1, T4, T5	
R&D Technical Report (P3-057/TR) and Project Record (P3-057/TR). Micro-scale variability in contaminants in surface sediments. S.M. Mudge, D.J. Assinder and A.T. Russell. Environment Agency, December 2001	This study has determined the magnitude of variability at the micro-scale (1m x 1m) in sediments, and hence provides a robust protocol for sampling estuarine sediments.	Guidance	C6	

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Environment Agency R&D Technical Report (P3-093/TR) and Project Record (P3-0937/TR). Meso-scale variation of radionuclides in sediments and implications for sampling. S.M. Mudge, D.J. Assinder and A.T. Russell.	This study has established normalised procedures, and produced sampling protocols, that reduce the variability in contaminant concentrations due to a number of environmental factors.	Guidance	C6	
Landfill engineering: Leachate drainage, collection and extraction systems. R&D Technical Report (P1-379/TR). Environment Agency, Bristol, 2002.	A literature search undertaken to assess and summarise the best practice for landfill leachate, collection and extraction systems.	Guidance	T15	Not specific to radioactivity
The microbiology of sewage sludge. Part 2: Practices and procedures for sampling and sample preparation. Environment Agency 2003	Provides issues relevant to the sampling of sewage sludge for microbiological analysis. General principles of sampling apply to other determinands.	Guidance	T16	Not specific to radioactivity
General principles for sampling airborne radioactive materials. BS5243:1975, ISO 2889:1975	Provides general principle to obtaining representative samples of airborne radioactive materials for gas and particle sampling.	Standard (International)	T2,	BS & ISO do not conflict
Monitoring of radioactive substances in ambient air around nuclear licensed sites: monitoring protocol. K.W. Nicholson and A. Collings. Draft 2, 2 May 2004, Environment Agency (in draft)	Provides a practical approach for the installation of air samplers for the collection and assessment of aerosol-borne radionuclides resulting from atmospheric releases.	Guidance	T2	
European calibration and co-ordination of mobile and airborne gamma spectrometry (ECCOMAGS)	The project aims to demonstrate the traceability of airborne gamma spectrometry to international standards in addition to increasing the accuracy and awareness of the technique.	Guidance	T20	
Special issue on environmental radiometrics. Journal of Environmental Radioactivity, 53 (2001)	Contains a series of papers covering a range of topics, including problems with continental scale mapping, case studies of base line studies and contaminated sites, and the development of seabed spectrometry.	Guidance	T20, C2	
Review of the procedures currently used for the monitoring of Sandside Bay. M.J. Youngman and G. Etherington. NRPB-DA/3/2003, April 2003	Provides a review of the procedures used for monitoring of Sandside beach adjacent to the Dounreay nuclear research facility at Caithness has been conducted. This monitoring was carried out to detect particles of irradiated fuel.	Guidance	C3	

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Guidance on the choice, use and maintenance of hand-held radiation monitoring equipment. P.H. Burgess. NRPB-R326 May 2001	Report designed to assist users to choose appropriate radiation monitoring equipment (does rate and contamination monitoring). Provides guidance on surveying techniques and instrumentation maintenance.	Guidance		
The development of field-based measurement methods for radioactive fallout assessment (2002). Health Physics, 82, 5, pages 609-625. K.M. Miller and R.J. Larsen.	Provides an overview of the development of field equipment, instrument systems, and methods of analyses that were used to assess the impact of radioactive fallout from atmospheric weapons tests. Developments include fallout collection and aerial measurement systems.	Guidance	T1, T3	
Compliance monitoring for remediated sites. Chapter 4. IAEA-TECDOC-1118, October 1999	Includes an overview of monitoring techniques (measurements and sampling).	Guidance	T1	
Collection and preparation of bottom sediment samples for analysis of radionuclides and trace elements. IAEA-TECDOC-1360, July 2003	Provides information on the methods for collecting sediments, the equipment used, and the sample preparation techniques for radionuclide and trace metals.	Guidance	T14, C6	
Soil sampling for environmental contaminants. IAEA-TECDOC-1415, October 2004	A review to evaluate existing techniques with regard to their practicability, reliability and applicability to different purposes.	Guidance	T5	
Cereals and pulses - Determination of hidden insect infestation - Part 2: Sampling. ISO 6639-2:1986	Shows general principles, apparatus, sampling times and places, pre-sampling inspection and identification of lots, sampling of bilk grain, sampling of grain in bags, preparation of laboratory sample, and packing, labelling and dispatch of laboratory samples.	Standard	T10	under development (ISO/AWI 6639-2) not specific to radioactivity
Comparison of techniques for the removal of particulate material from seaweed tissue (1998). Marine Environmental Research, 45, 295-301. Gledhill M., Brown M.T., Nimmo M., Moate R. and Hill S.J.	Illustrates the requirement for standard methods for sampling (and analysis) seaweed tissue.	Guidance	C7	not specific to radioactivity
Sample preparation (cleaning, drying, and homogenisation for trace element analysis in plant matrices (1995). Science of the Total Environment, 176, 45-61. B. Markert	The paper describes the approaches to cleaning, drying and grinding of plant matrices.	Guidance	T7, T10	Not specific to radioactivity

Reference source	Summary	Status	Sampling / monitoring type (codes given in Table 1)	Notes
Guide for the control of molluscan shellfish. US National Shellfish Sanitation Programme US FDA/CFSAN & ISSC - NSSP 2003	Provides guidance on the growing and processing of molluscan shellfish for human consumption.	Guidance	C9	Not specific to radioactivity
EU good practice guide on the microbiological monitoring of shellfish harvesting areas (in draft)	Provides guidance on the collection and processing of molluscan shellfish for human consumption.	Guidance	C9	Draft not available (expected 2006) - not specific to radioactivity
Guidance for assessing chemical contaminant data in fish. Volume 1: Fish sampling and analysis. EPA 823-B-00-007, November 2000	Provides extensive guidance on the methods for sampling and analysing contaminants in fish and shellfish.	Guidance	C8, C9	Not specific to radioactivity

Table 3a: Summary of costs, risks/weaknesses and benefits/strengths of alternative approaches - Inter-tidal monitoring

Sample Type	Objective	Comparison	Costs	Risks/Weaknesses	Benefits/Strengths
Estuary/coastal contamination monitoring – strandline and small particles and objects.	• ***Reassurance / investigation*** – to look for anomalies (areas of elevated activity) and to detect and remove any hot particles (defined by significantly elevated count rate) or objects with elevated activity on beaches.	Survey by foot	• Sweep detector (e.g. Geiger - Muller detector, NaI(Tl) for gamma emitters, large area scintillation or proportional detector for beta emitters). • Routine maintenance and calibration. • Repairs. • Field staff time.	• Failure of detector (mechanical or detector window being punctured by ground debris, cable damage). • Length of time taken for survey may be substantial. • GM detectors are becoming obsolete.	• Can be used where access is restricted or ground uneven. • Rapid qualitative data. • Detection of 'hot spots'. • Cheap detectors. • Established methodology.
		Survey by vehicle	• Mobile detector (such as NaI (Tl) for gamma sources) and attachment mounts/brackets for vehicles. • Routine maintenance and calibration. • Repairs (instruments/vehicles). • Hire/purchase of vehicles. • Field staff time.	• Failure of detectors and vehicles. • Inability of vehicle to traverse difficult terrain.	• Effective and efficient in covering larger areas and in less time.
		Recommended method: Foot surveys should be used when access or terrain is difficult. Vehicle surveys should be used to monitor larger areas (such as beaches) where access and terrain are suitable.			

Table 3a: Continued – Inter-tidal monitoring

Sample Type	Objective	Comparison	Costs	Risks/Weaknesses	Benefits/Strengths
Estuary dose rate	• ***Critical group dose*** - To provide measurements of external radiation dose from radionuclides incorporated in sediments. • ***Model check*** - To check reported discharges and dispersion and dose rate models. • ***Baseline*** - Routine monitoring also provides baseline levels in the event of a radiological incident. • ***Reassurance –*** To detect abnormal releases and to reassure members of the public using inter-tidal areas.	Passive detectors (such as TLDs)	• Device (could use naturally occurring TLDs such as quartz, feldspars). • Analytical costs. • Field and lab staff time.	• Uncertainty due to environmental damage, vandalism and contamination. Need to ensure security. Retrieval rate is likely to be much less than 100%. • Relatively expensive (staff/analytical) for frequent surveys. • Delayed results. • Uncertainty in device until analysis completed. • Quartz feldspars may have issues knowing how long the exposure time has been. • Uncertainty due to bleaching effects of UV and the high self-dose.	• Cheaper for infrequent surveys. • Less staff time. • Pre-calibrated from manufacturer. • No maintenance or breakdown costs.
		Spot dose rate measurement (e.g. using Mini-6-80 or energy compensated NaI(Tl) detector for gamma)	• Instrument. • Routine maintenance and calibration. • Repairs. • Field staff time.	• Instrument failure (mechanical or operation in field). • Some instruments (such as Mini 6-80) overly sensitive to cosmic radiation. • Need to correct for influence of cosmic radiation, natural background and detector intrinsic dose rate.	• Quick quantitative results on site. • Established methodology.
		Recommended method: Spot dose rate measurements are the preferred method as the security of passive detectors in an inter-tidal environment cannot generally be assured.			

Table 3a: Continued – Inter-tidal monitoring

Sample Type	Objective	Comparison	Costs	Risks/ Weaknesses	Benefits/ Strengths
Estuary/coastal sediments	• ***Investigative / model check*** – To provide check of historical discharges and sea dispersion modelling.	Sediment cores and laboratory analysis	• Sampling equipment. • Maintenance of sampling equipment. • Field staff time.	• Failure of corer. • Penetration of corer of sand/gravel.	• Quantitative results. • Depth profile with results.
		In situ gamma spectrometry	• Detector/Equipment. • Routine maintenance and calibration. • Repairs. • Field staff time.	• Ill-defined averaging volume. • No background shielding and, hence, influenced by local natural high dose rates. • Need to establish calibration. • Results will at best have greater uncertainty than for laboratory analysis of core samples. The results may only be useful as a semi-quantitative screen in some cases. • Only gamma-emitting radionuclides detected. • Failure of instrument (mechanical or weather). • Need for a continuous power source.	• Once calibrated, no need to take sediment samples and hence no preparation and laboratory analytical costs. • Better integration of concentration over a wider area and depth. • Can be used to help to identify where samples should be collected for laboratory analysis. • Coupling to GPS system gives easy data presentation.
		Recommended method: Sediment cores and laboratory analysis is the preferred method to achieve these objectives. However, in situ gamma spectrometry can be used as a complementary technique to help identify the best location to take sediment cores.			

Table 3b: Summary of costs, risks/weaknesses and benefits/strengths of alternative approaches - Terrestrial monitoring

Sample Type	Objective	Comparison	Costs	Risks/ Weaknesses	Benefits/ Strengths
Dose rate monitoring	• ***Critical group dose*** - To provide measurements of external radiation dose from airborne and deposited radionuclides and direct radiation to assess total external dose to the most exposed (critical) population groups. • ***Baseline*** - Routine monitoring also provides baseline levels in the event of a radiological incident.	Passive detectors (such as TLDs)	• Device. • Analytical costs. • Field and lab staff time.	• Uncertainty due to environmental damage, vandalism and contamination. Need to ensure security. • Relatively expensive (staff/analytical) for frequent surveys. • Delayed results. • Uncertainty in device until analysis completed. • Reference background value required.	• Cheaper for infrequent surveys. • Less staff time. • Pre-calibrated from manufacturer. • No maintenance or breakdown costs.
		Spot dose rate measurement (e.g. using Mini-6-80 or energy compensated NaI(Tl) detector for gamma)	• Instrument. • Routine maintenance and calibration. • Repairs. • Field staff time.	• Will not give an appropriate measure of dose rate for assessing critical group dose, if this dose rate fluctuates. • Instrument failure (mechanical or operation in field). • Need to correct for the influence of cosmic radiation, natural background and detector intrinsic dose rate.	• Quick quantitative results on site. • Established methodology.
		Recommended method: Passive detectors are suitable where their security can be assured and if dose rates are fluctuating, such that it is important to get a measure of the integrated dose rate. Spot measurements are appropriate if security is poor or if dose rates are relatively stable.			

Table 3b: Continued – Terrestrial monitoring

Sample Type	Objective	Comparison	Costs	Risk/ Weaknesses	Benefits/ Strengths
Air sampling	• ***Critical group dose*** - Inhalation exposure pathway for particulate radionuclides. • ***Reassurance –*** To detect abnormal releases. • ***Model check*** – To check reported discharges and air dispersion modelling. • ***Environmental indicator*** - To monitor the long-term concentrations of radionuclides in air from routine releases, resuspension and sea to land transfer.	Passive shades	• Specialist material and frames. • Staff collection time. • Requires meteorological data (wind speed and direction) to help understanding.	• Cannot derive air concentrations that are required to achieve critical group dose and model check objectives. • Damage to cloths and frames (weather and vandalism). • Delayed qualitative results and not quantitative. •	• Cheaper start-up costs. • Low maintenance. • No breakdown costs. • Possible use for quick identification of trends. • Quicker and easier than grass sampling and other depositional-based measures.
		High/Medium Volume Air Sampling (HVAS/MVAS)	• HVAS/MVAS sampler. • Routine maintenance and calibration. • Repairs. • Field staff time. • Need to tune the time sampling window to particle size range being targeted to avoid blockages. • Requires met data (wind speed and direction) to help understanding.	• Failure of instrument (mechanical or weather). • Continuous power source required. • Semi-quantitative results possible (due to large particles which may block the sampling window). • Inlet and wall losses produce errors in results (need to detect efficiency of device and compensate). • Delayed results.	• Quantitative results and so all objectives are adequately achieved.
		Recommended method: High Volume Air Sampling is the recommended method if the objective is to derive air concentrations which can be used to assess critical group doses and check models. Passive shades have some value in providing a cheaper means to identify that an abnormal release has occurred.			

Table 3b: Continued – Terrestrial monitoring

Sample Type	Objective	Comparison	Costs	Risk/ Weaknesses	Benefits/ Strengths
Soil	• ***Model check*** – To check historical discharges and air dispersion/deposition modelling. • ***Baseline*** – To provide a baseline in the event of a radiological incident.	Soil cores and laboratory analysis	• Sampling equipment. • Field and lab staff time.	• No results on site.	• Quantitative results. • More accurate results due to further preparation before counting. • Likely to have more than one detector. • Established methodology.
		In situ gamma spectrometry	• Detector/Equipment. • Routine maintenance and calibration. • Repairs. • Field staff time.	• Need to establish calibration. • Ill-defined averaging volume. • No background shielding and, hence, influenced by local natural high dose rates. • Results will at best have greater uncertainty than for laboratory analysis of core samples. The results may only be useful as a semi-quantitative screen in some cases. • Only gamma-emitting radionuclides detected. • Failure of instrument (mechanical or weather). • Need for a continuous power source.	• Once calibrated, no need to take soil samples and hence no preparation and laboratory analytical costs. • Better integration of concentration over a wider area and depth. • Can be used to help identify where samples should be collected for laboratory analysis. • Coupling to GPS system gives easy data presentation.
		Recommended method: Soil cores and laboratory analysis are the preferred methods to achieve these objectives. However, in situ gamma spectrometry can be used as a complimentary technique to help identify the best location to take soil cores.			

Table 3b: Continued – Terrestrial monitoring

Sample Type	Objective	Comparison	Costs	Risk/ Weaknesses	Benefits/ Strengths
Freshwater sediments	***Investigative/model check*** – To investigate the impact of historical discharges and check models against these discharges.	Sediment cores and laboratory analysis.	• Sampling equipment. • Maintenance of sampling equipment. • Field staff time.	• Failure of corer. • Penetration of corer of sand/gravel.	• Quantitative results. • Depth profile with results.
		In situ gamma spectrometry	• Detector/Equipment. • Routine maintenance and calibration. • Repairs. • Field staff time.	• Need to establish calibration. • Ill-defined averaging volume. • No background shielding and, hence, influenced by local natural high dose rates. • Results will at best have greater uncertainty than for laboratory analysis of core samples. The results may only be useful as a semi-quantitative screen in some cases. • Only gamma-emitting radionuclides detected. • Failure of instrument (mechanical or weather). • Need for a continuous power source.	• Once calibrated, no need to take sediment samples and hence no preparation and laboratory analytical costs. • Better integration of concentration over a wider area and depth. • Can be used to help identify where samples should be collected for laboratory analysis. • Coupling to GPS system gives easy data presentation.
		Recommended method: Sediment cores and laboratory analysis are the preferred methods to achieve these objectives. However, in situ gamma spectrometry can be used as a complimentary technique to help identify the best location to take sediment cores.			

Table 4a: Best practice environmental monitoring guidance – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Estuary/coastal dose rate monitoring	• ***Critical group dose*** - To provide measurements of external radiation dose from radionuclides incorporated in sediments. • ***Model check*** - To check reported discharges and dispersion and dose rate models. • ***Baseline*** - Routine monitoring also provides baseline levels in the event of a radiological incident. • ***Reassurance –*** To detect abnormal releases and to reassure members of the public using inter-tidal areas.	• Identify and note sediment type and weather conditions. • Select instrument to take spot measurement (such as Mini 6-80, energy compensated NaI(Tl) detector). • Instrument should meet defined performance criteria, to include [Ref 6]: - Inherent background dose rate <0.015 μGy/h ^{226}Ra γ - Cosmic ray response <0.07 μGy/h ^{226}Ra γ - Air kerma based response ± 30 % of the response to ^{137}Cs γ radiation over the energy range 80 keV to 1.25 MeV - Adequate polar response - Precision • Establish cosmic and intrinsic background. • Ensure instrument is calibrated regularly (e.g. annually). • Ensure instrument is functioning before and after monitoring survey period (or weekly). • Correct measurements for cosmic and intrinsic detector background. • Results reported as μGy/h over sediment type (including natural background).	• Take measurement at height of 1 m. • Operator should stand at least 10 m away from the detector to prevent effects of shielding. • Take reading over sufficient time period to achieve sufficient statistical confidence at the defined minimum dose rate measurement limit. • Take measurements to ensure dose rate is representative over a scale of up to 5-10 m. Normally, a single dose rate measurement (e.g. Mini 6-80) will be representative at this scale, although dose rate can be measured at 2-3 locations at distances of 10 m apart over the same ground type and an average result reported. • Note that where geology is changing rapidly, it may be difficult to choose a reference background dose rate for comparison.	-

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Estuary/coastal dose rate monitoring (cont)	• ***Critical group dose*** - To establish β and γ dose rate over sediments to enable doses to people in close proximity to them (such as seated anglers) to be assessed.	• Identify and note sediment type and weather conditions. • Select instrument to take spot measurements (e.g. Berthold 122) • Instrument should meet defined performance criteria, to include: - Detection efficiency / sensitivity capability - Precision - Energy response that matches the quantity of interest • Ensure instrument is calibrated regularly (e.g. annually). • Ensure instrument is functioning before and after monitoring survey period (or weekly). • Results reported as µGy/h over sediment type (including natural background).	• The height at which to take the measurement should be appropriate to the habit being assessed (e.g. 15 cm for seated anglers). • Take appropriate number of readings across the surface, to be representative of the item being monitored, with shield on (γ only) and without shield (β and γ). • Take reading over sufficient time period to achieve defined dose rate measurement limit (using integrating function of instrument).	-

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Estuary/coastal contamination monitoring – strandline and small particles and objects (***by foot***)	• ***Reassurance / investigation*** – To look for anomalies (areas of elevated activity) and to detect and remove any hot particles (defined by significantly elevated count rate) or objects with elevated activity on beaches.	• Monitoring by foot where this is more cost effective than monitoring by vehicle. • Identify and note point in the tidal cycle. Allow for tide times to ensure access. • Identify and note the weather conditions. • Select instrument to take measurements (e.g. probe with Geiger-Muller detector) • Instrument should meet defined performance criteria (to enable a hot particle as defined to be detected), to include: - Detection efficiency / sensitivity capability - Precision - Detector should be chosen to maximise the ability to detect the potential contaminant taking account of the local background - Response time • Ensure instrument is calibrated regularly (e.g. annually). • Ensure instrument is functioning before and after monitoring survey period (or weekly). • Results reported as counts/s. • Also µSv/h from the hot particle or object (if appropriate conversion factors available).	• Monitor strandline (order of importance; most recent tide-line, the extreme high water mark and wind blown debris above the extreme high water mark) by walking with instrument. Crevices can be investigated as necessary. • Probe should be kept just above the ground surface and moved in side-to-side sweeps at a defined rate allowing for instrument response time (e.g. < 0.5 m/s). Looking to detect an increase in counts. • Procedures should be defined for what action to take if a hot particle is found. These will need to address health and safety requirements, responsibility for custody and detailed analytical requirements. • If increased count rate is associated with a wider area of contamination. may need to move in to a characterisation phase to determine its extent. • Record general count rate range for the defined transect that has been surveyed.	-

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Estuary/coastal contamination monitoring – strandline and small particles and objects (***by vehicle***)	• ***Reassurance / investigation*** – To look for anomalies (areas of elevated activity) and to detect and remove any hot particles or objects with elevated activity on beaches.	• Monitoring by vehicle where this is more cost effective than monitoring by foot. • Identify and note point in the tidal cycle. Allow for tide times to ensure access. • Identify and note the weather conditions. • Select instrument to take measurements (such as NaI (Tl) detectors, vehicle/detectors) • Instrument should meet defined performance criteria (to enable a hot particle as defined to be detected), to include: - Detection efficiency / sensitivity capability - Precision - Detector should be chosen to maximise the ability to detect the potential contaminant taking account of the local background - Response time • Ensure instrument is calibrated regularly (e.g. annually). • Ensure instrument is functioning before and after monitoring survey period (or weekly). • Results reported as µSv/h from the hot particle or object (if appropriate conversion factors available).	• Rate of vehicle travel to be defined to allow for time for the instrument response and defined detection criteria to be met. • Travel the area using sweeps at intervals to meet defined detection criteria. • Procedures should be defined for what action to take if a hot particle is found. These will need to address health and safety requirements, responsibility for custody and detailed analytical requirements. • If increased count rate is associated with a wider area of contamination, may need to move in to a characterisation phase to determine its extent. • Record general count rate range for the defined transect that has been surveyed.	-

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Estuary/coastal contamination monitoring – areas where hot particles are prone to accumulate.	• ***Reassurance / investigation*** – To look for hot particles in areas where they are prone to accumulate.	• See Nairn conference proceedings [Ref 14]	-	-
Contamination monitoring of objects (ropes, nets, lobster pots)	• ***Critical group dose*** - To establish β and γ contact dose rate to enable dose to skin to be assessed. • ***Reassurance*** – To provide reassurance to fishermen and other users	• Select instrument to take spot measurements (e.g. Berthold 122) • Instrument should meet defined performance criteria, to include: - Detection efficiency / sensitivity capability - Precision - Energy response that matches the quantity of interest - Appropriate calibration factor developed • Ensure instrument is calibrated regularly (e.g. annually). • Ensure instrument is functioning before and after monitoring survey period (or weekly). • Results reported as μGy/h.	• Take measurement at just above the material being monitored, ensuring that window membrane is not punctured. • For ropes and nets, monitor in the manner used by fishermen. • Take appropriate number of readings across the surface, to be representative of the item being monitored, with shield on (γ only) and without shield (β and γ). • Take reading over sufficient time period to achieve defined dose rate measurement limit (using integrating function of instrument).	-

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Seawater	• ***Critical group dose*** **–** External dose and dose from inadvertent consumption of seawater during leisure activities or fishing activities. • ***Wildlife*** **–** To determine doses to wildlife. • ***Environmental indicator*** - To monitor the long-term concentrations. Provide precursory information with regard to incorporation of radionuclides in sediment, fish and shellfish. • ***Baseline*** – To provide a baseline in the event of a radiological incident.	• Beach collection of seawater samples. • Minimise adsorption of radionuclides to container (for example, pre-soak containers and use carrier solutions). • Report results as Bq/l.	• Allow for tide times to ensure access (for beach collection). • Rinse collection apparatus and container with sample. • Collect water (use water submersible pump for large volume samples or bucket/carboy for small volume samples). • Continuous automatic sampling maybe required. • Store the sample to prevent deterioration in transit to the lab (for example in cool, dark conditions, cool box).	• Store samples at laboratory to minimise growth of algae and avoid degradation of sample (e.g. chill at about 4^{o}C in the dark). • Filter samples through a 0.45 µm membrane and analyse filtrate and residue if the monitoring objective requires information on the partitioning between dissolved and particulate phases. • Ensure representative sub-sample is taken for analysis (e.g. shake water sample). • Concentrate sample if needed (for example, through ion exchange or evaporation). • Preserve with nitric acid for long storage (analysis dependent).
	• ***Model check*** – To check historical discharges and sea dispersion modelling. • ***Distribution -*** To provide an inventory in a given area.	• Need to determine whether beach collection would meet the monitoring objective. • May involve sampling offshore in a boat. • Need to determine whether surface water, samples from depth, averaged water column samples are required to meet monitoring objective. • Minimise adsorption of radionuclides to container (for example, pre-soak containers and use carrier solutions). • Report results as Bq/l.	• Rinse collection apparatus and container with sample. • Collect representative sample from water surface or at depth using pump or containers which are triggered to collect a sample at a particular depth. • Store the sample to prevent deterioration in transit to the lab (for example in cool, dark conditions, cool box).	• Store samples at laboratory to minimise growth of algae and avoid degradation of sample (e.g. chill at about 4^{o}C in the dark). • Filter samples through a 0.45 µm membrane and analyse filtrate and residue if the monitoring objective requires information on the partitioning between dissolved and particulate phases. • Ensure representative sub-sample is taken for analysis (e.g. shake water sample). • Concentrate sample if needed (for example, through ion exchange or evaporation). • Preserve with nitric acid for long storage (analysis dependent).

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Estuary/coastal sediments	• ***Critical group dose*** - To determine the potential source of exposure through inhalation and inadvertent ingestion during recreational activities. • ***Wildlife*** **–** To determine doses to wildlife.	• Allow for tide times to ensure access. • Ensure depositional environment. • Report results as Bq/kg (dry weight).	• Take samples from predominant sediment type. • Obtain a reasonably representative sample over a scale of up to 5-10 m. This may be achieved by collecting five surface sediment samples from the points of a W shape or the ends and centre of an X shape over a circle of 10 m diameter. The samples may be bulked. • Collect surface sediment samples (0-1 cm) with flat hand shovel (or appropriate tool) over selected area.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight and preventing fusing of sample (e.g. oven dry 40-105^{o}C or freeze dry). (May need to analyse wet for volatile radionuclides). • Record dry/wet ratio. • Remove gravel component by sieving to <2 mm and discarding >2 mm fraction. • Ensure representative sub-sample is taken for analysis (for example, by grinding and coning and quartering).
	• ***Environmental indicator*** - To monitor the impact of recent discharges on environmental concentrations. • ***Distribution*** **–** Examine areas of deposition/concentration.	• As above	• As above	• As above • May need to normalise or report factors which can influence concentrations such as grain size (loss on ignition at 450°C a good proxy[Ref 11]) and total organic carbon, or restrict grain size (e.g. <250 μm).

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Estuary/coastal sediments (cont)	• ***Investigative / model check*** - To provide check of historical discharges and sea dispersion modelling.	• Allow for tide times to ensure access. • Identify sample location with depositional history. • Report results as Bq/kg (dry weight).	• Take core samples using an appropriate device (able to withstand saline environment). • Obtain a reasonably representative sample over a scale of up to 5-10 m. This may be achieved by collecting five cores from the points of a W shape or the ends and centre of an X shape over a circle of 10 m diameter. • The depth of the core should enable the monitoring objectives to be achieved. It should be noted that longer cores can be affected by compression, with this being greatest near the (wetter) top. Account of this will need to be taken when preparing the core further. • Section core into slices which enable the monitoring objectives to be achieved. Cores are typically sectioned into 5-10 cm slices. Clean core sectioning tool (blade) between slices. • Sub-sample from centre of each core slice to reduce smearing. • The same sections of cores may be bulked together as appropriate.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight and preventing fusing of sample (e.g. oven dry 40-105^{o}C or freeze dry). (May need to analyse wet for volatile radionuclides). • Record dry/wet ratio. • Remove gravel component by sieving to <2 mm and discarding >2 mm fraction. • Ensure representative sub-sample is taken for analysis (for example, by grinding and coning and quartering).

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Seaweed	• ***Environmental indicator*** – Provides a good indicator of recent discharges, particularly for more soluble radionuclides. • ***Model check*** – To check historical discharges and sea dispersion modelling.	• Consider seasonal (annual) cycle on sampling strategy. • Selection of recent growth for analysis will provide a better indicator of recent discharges than analysis of a whole frond which will lead to an indicator of integrated discharges over a few years. • Report results as Bq/kg (fresh weight)	• Allow for tide times to ensure access (for beach collection). • Correctly identify single species (including hybrids) as determined to meet objective. • Collect and trim recent growth from fronds. • Note presence of fruiting bodies which may affect results, due to changes in plant physiology. • Wash in water to remove particulate and epiphytes. • Store sample to prevent deterioration in transit to the lab (for example in cool, dark conditions, cool box).	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight (e.g. air dry, oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/fresh ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sampled in mill or blender or blending fresh samples, Cone and quarter if appropriate).
	• ***Critical group dose*** – To assess dose to exposed population groups from consumption as food.	• Consider seasonal (annual) cycle on sampling strategy. • Report results as Bq/kg (fresh weight)	• Allow for tide times to ensure access (for beach collection). • Correctly identify food species. • Collect fresh seaweed (recent growth) or parts used for food according to local practice. • Wash in water to remove particulate and epiphytes. • Store the sample to prevent deterioration in transit to the lab (for example, in cool, dark conditions, cool box).	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight (e.g. air dry, oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/fresh ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sampled in mill or blender or blending fresh samples, Cone and quarter if appropriate).

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Seaweed (cont)	• ***Critical group dose –*** To assess dose from use of seaweed as compost and consumption of food.	• Consider seasonal (annual) cycle on sampling strategy. • Report results as Bq/kg (fresh weight)	• Allow for tide times to ensure access (for beach collection). • Correctly identify the species used for compost and collect sample (according to local practice). • Store the sample to prevent deterioration in transit to the lab (for example in cool, dark conditions, cool box).	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight (e.g. air dry, oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/fresh ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sampled in mill or blender or blending fresh samples, Cone and quarter if appropriate).

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Fish	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in fish. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated foodstuffs. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in foodstuffs arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Distribution*** **–** Determine the spread of radionuclides through foodstuffs/the environment from radioactivity arising from routine authorised releases • ***Model check*** – Provide data that, along with other monitoring of sediment and seawater, may be useful to check reported discharges and dispersion and transfer models.	• Select species to meet monitoring objective (for example, benthic versus pelagic, stage of growth, availability in the fishing ground). • Report results as Bq/kg (fresh weight).	• Correctly identify species caught by net or line. • Store the sample to prevent deterioration in transit to the lab (for example in cool, dark conditions, cool box).	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Prepare the raw edible fraction for analysis. Culinary preparation may need to be taken into account. • Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/wet ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate).

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Fish (cont)	• ***Wildlife*** **-** To determine the radiological exposure to fish.	• As above	• As above	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Prepare samples as a whole (including entrails) OR prepare specific portion of sample (such as the thyroid). • Record weights of parts required for analysis and for discarded parts (to allow for total body burden). • Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/wet ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate).

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Crustaceans/ Molluscs	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in crustaceans/molluscs. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated foodstuffs. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in foodstuffs arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Distribution*** **–** Determine the spread of radionuclides through foodstuffs/the environment from radioactivity arising from routine authorised releases • ***Model check*** – Provide data that, along with other monitoring of sediment and seawater, may be useful to check reported discharges and dispersion and transfer models.	• Select species to meet monitoring objective. • Report results as Bq/kg (fresh weight).	• Correctly identify species. • Collect by hand sampling or using pots or digging as appropriate for species. • Do not depurate. • Store the sample to prevent deterioration in transit to the lab (for example, in cool, dark conditions, cool box).	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Prepare the raw edible fraction for analysis. Culinary preparation may need to be taken into account. • Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/wet ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate).

Table 4a: Continued – Inter-tidal monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Crustaceans/ Molluscs (cont.)	• ***Wildlife*** **-** To determine the radiological exposure to crustaceans/molluscs.	• As above	• As above	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4°C or freeze). • Prepare softer-shelled species (such as shrimps) whole. For harder-shelled species (such as lobsters, whelks) prepare samples in two portions: 1) flesh and 2) shell. Treat as two separate samples in subsequent stages OR prepare specific portion of sample (such as the gut). • Record weights of parts required for analysis and for discarded parts (to allow for total body burden). • Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/wet ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate).

Table 4b: Best practice environmental monitoring guidance – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Dose rate monitoring (fluctuating dose rates and secure location)	• ***Critical group dose*** - To provide integrated measurements of external radiation dose from airborne and deposited radionuclides, and direct radiation. Close to nuclear establishments, there may also be a significant contribution due to direct radiation (shine) from the site and this monitoring therefore provides a measure of total external dose to the most exposed (critical) population groups. • ***Baseline*** - Routine monitoring also provides baseline levels in the event of a radiological incident.	• Select passive dose rate monitor (such as TLD, film badge). • Instrument should meet defined performance criteria. • Ensure secure location. • Establish cosmic background. • Results reported as μGy/h air kerma (state whether corrected for cosmic).	• Locate at height of 1 to 1.5 m in a secure location. • Locate such that shielding from source of exposure is minimised (for example away from walls, trees, hedges and roads). • Instruments to be deployed to meet defined dose rate measurement limit subject to a maximum period of 3 months to minimise loss of monitoring data if instrument is lost/fails. • Take measurements to ensure dose rate is representative over a scale of up to 5-10 m. This may be checked with spot dose rate measurements.	-

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Dose rate monitoring (non-fluctuating dose rates or non-secure location)	• ***Critical group dose*** - To provide spot measurement of external radiation dose from airborne and deposited radionuclides, and direct radiation. Close to nuclear establishments, there may also be a significant contribution due to direct radiation (shine) from the site and this monitoring therefore provides a measure of total external dose to the most exposed (critical) population groups. • ***Baseline*** - Routine monitoring also provides baseline levels in the event of a radiological incident.	• Select instrument to take spot measurement (for example, Mini 6-80, energy compensated NaI(Tl) detector). • Instrument should meet defined performance criteria, to include [Ref 6]: - Inherent background dose rate <0.015 µGy/h ^{226}Ra γ - Cosmic ray response <0.07 µGy/h ^{226}Ra γ - Air kerma based response $\pm$ 30 % of the response to ^{137}Cs γ radiation over the energy range 80 keV to 1.25 MeV - Adequate polar response - Precision • Establish cosmic and intrinsic background. • Ensure instrument is calibrated regularly (e.g. annually). • Ensure instrument is functioning before and after monitoring survey period (or weekly). • Correct measurements for cosmic and intrinsic detector background. • Results reported as µGy/h air kerma.	• Take measurement at height of 1 m. • Locate such that shielding from source of exposure is minimised (for example away from walls, trees, hedges and roads). • Take reading over sufficient time period to achieve sufficient statistical confidence at the defined minimum dose rate measurement limit. • Take measurements to ensure dose rate is representative over a scale of up to 5-10 m. Normally, a single dose rate measurement (e.g. Mini 6-80) will be representative at this scale, although dose rate can be measured at 2-3 locations at distances of 10 m apart over the same ground type and an average result reported). • Note that where geology is changing rapidly it may be difficult to choose a reference background dose rate for comparison	-

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
High/Medium Volume Air Sampling (HVAS / MVAS)	• ***Critical group dose*** - Inhalation exposure pathway for particulate radionuclides. • ***Reassurance –*** To detect abnormal releases. • ***Model check*** – To check reported discharges and air dispersion modelling. • ***Environmental indicator*** - To monitor the long-term concentrations of radionuclides in air from routine releases, resuspension and sea to land transfer.	• Ensure secure site and power supply. • Ensure noise is minimised. • HVAS/MVAS needs to collect total particulate (not specific size range) – this is cautious for the objectives. • Air flow to be measured with defined uncertainty (best practice instrument maintain flowrate automatically) – calibration will be required. • Filters should trap >95% of particle size >0.3 μm AMAD [Ref 7]. • Mass of particulate collected to be measured (e.g. filters weighed before and after collection). • Results reported as Bq/m^3.	• Cross-contamination to be avoided (for example, seal in polythene bags, take blank filters to field). • Ensure filters can be identified (for example, uniquely label filters). • Sample for a period to ensure that defined detection limits can be achieved and avoid filter blinding (two weeks is typical).	-

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Total deposition (wet and dry)	• ***Environmental indicator*** – To monitor the long-term deposition of radionuclides from routine releases. • ***Model check*** –To provide field data to check reported discharges and air dispersion and deposition modelling. • ***Reassurance*** – To detect abnormal releases.	• Collect in a deposition collector (such as a rain gauge). • Minimise adsorption of radionuclides to container (for example, pre-soak containers and use carrier solutions). • Minimise growth of algae (for example, use brown collection bottle). • Report results as Bq/l or $Bq/m^2/s$.	• Record area of collection funnel and duration of time sample collected. • Ensure sample collection period will not cause sample container to over-flow, but sufficient sample is collected to ensure detection limit can be achieved. A typical collection period is 2-4 weeks.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^oC). • Filter samples through a 0.45 µm membrane and analyse filtrate and residue if the monitoring objective requires information on the partitioning between dissolved and particulate phases (e.g. particulate deposition). • Ensure representative sub-sample is taken for analysis (for example, shake liquid samples). • Bulk or concentrate samples (for example, through ion exchange or evaporation) to achieve detection limits, if required.

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Grass/ Herbage	• ***Environmental indicator*** – To indicate whether there is likely to be significant concentrations in milk, which is an important exposure pathway. • ***Reassurance –*** To detect abnormal releases. Can be more sensitive than milk as animals graze over a large area. • ***Model check*** – To check reported discharges and air dispersion/deposition modelling.	• Area may be fenced off to prevent removal of grass and unwanted additions (such as animal droppings, fertiliser). Also enables growth since last sample to be collected. • Samples should be collected at same location as soil samples if the objective is to validate dispersion, deposition and transfer modelling. • Report results as Bq/kg (fresh weight) and Bq/m^2.	• Obtain a reasonably representative sample over a scale of up to 5-10 m from a known total area. This may be achieved by collecting five grass samples from a 0.25 - 1 m^2 quadrat at the points of a W shape or the ends and centre of an X shape over a circle of 10 m diameter. Grass/herbage samples should be representative of that present at a scale of up to 5-10 m. The samples may be bulked. • Trim sample approx 10 mm above soil surface with shears (or similar), taking care not to collect any soil and excluding non-herbage (woody) material. • Store sample to prevent deterioration (for example, in an airtight container).	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^oC or freeze). • Dry sample to constant weight and prevent fusing of sample (e.g. oven dry 40-105^oC or freeze dry). (May need to analyse wet for volatile radionuclides). • Record dry/wet ratio. • Ensure representative sub-sample is taken for analysis (for example, use blender).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Soil	• ***Environmental indicator*** – To indicate whether there is likely to be significant transfer into grass, and hence into milk which is an important exposure pathway. • ***Model check*** – To check recent reported discharges and air dispersion/deposition modelling. • ***Wildlife*** – To determine doses to wildlife.	• Samples should be collected from undisturbed permanent pasture • The area may be fenced off to protect the collection site. • Samples of soil in the root zone should be collected to achieve these objectives (typically 2-5 cm). • It is normal to remove roots as far as reasonably practicable from the sample to achieve these objectives. However, it may be appropriate to include all the roots in the sample in certain circumstances. • Report results as Bq/kg (dry weight).	• Obtain a reasonably representative sample over a scale of up to 5-10 m. This may be achieved by collecting five soil samples from the points of a W shape or the ends and centre of an X shape over a circle of 10 m diameter [Ref 9,10]. The samples may be bulked. • Remove surface litter and overlying vegetation. • Collect soil samples such that excessive damage to the collection site is minimised and that the sample is to a known depth. This may be achieved by collecting 4–10 cm diameter cores to a depth of 5 cm.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight and prevent fusing of sample (e.g. oven dry 40-105^{o}C or freeze dry). (May need to analyse wet for volatile radionuclides). • Record dry/wet ratio. • Remove gravel component by sieving to <2 mm and discarding >2 mm fraction. • Ensure representative sub-sample is taken for analysis (for example, by grinding and coning and quartering).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Soil (cont)	• ***Model check*** – To check historical discharges and air dispersion/deposition modelling. • ***Baseline*** – To provide a baseline in the event of a radiological incident.	• Samples should be collected from undisturbed permanent pasture • The area may be fenced off to protect the collection site. • Samples will need to be sufficiently deep to achieve monitoring objectives. A typical practical depth is 15 cm. • Report results as Bq/kg (dry weight) and Bq/m^2.	• Obtain a reasonably representative sample over a scale of up to 5-10 m. This may be achieved by collecting five soil samples from the points of a W shape or the ends and centre of an X shape over a circle of 10 m diameter. The samples may be bulked. • Remove surface litter and overlying vegetation. • Collect soil samples such that excessive damage to the collection site is minimised and that the sample is to a known depth. This may be achieved by collecting 4–10 cm diameter cores to a depth of 15 cm. • Record the area of the sample (for example, the area of the core). • Section core into slices which enable the monitoring objectives to be achieved. Account may need to be taken of compression of the core, particularly for wet sediments. There is no need to section cores where the total deposition is being established for a baseline. Cores are typically sectioned into 5-10 cm slices. Clean core sectioning tool (blade) between slices. • Sub-sample from centre of each core slice to reduce smearing.	• As above

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Surface freshwater (such as rivers, streams, lakes)	• ***Critical group dose*** - To determine the dose from consumption of drinking water, consumption of irrigated crops and consumption of meat products where animals drink water. • ***Wildlife –*** To determine doses to wildlife. • ***Environmental indicator*** - To monitor the long-term concentrations. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Model check*** – To check historical discharges and air dispersion/deposition modelling.	• Determine appropriate sample container dependent upon radionuclide(s) to be sampled. • Report results as Bq/l.	• Rinse collection apparatus and container with sample. • Collect representative sample. • Store the sample to prevent deterioration in transit to the lab (for example in cool, dark conditions, cool box).	• Store samples at laboratory to minimise growth of algae and avoid degradation of sample (e.g. chill at about 4^{o}C in the dark). • Filter samples through a 0.45 µm membrane and analyse filtrate and residue if the monitoring objective requires information on the partitioning between dissolved and particulate phases. • Ensure representative sub-sample is taken for analysis (for example, shake water sample). • Concentrate sample if needed (for example, through ion exchange or evaporation). • Preserve with nitric acid for long storage (analysis dependent).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Freshwater sediments	• ***Critical group dose*** - To determine the potential source of exposure through inhalation and inadvertent ingestion during recreational activities. • ***Wildlife*** – To determine doses to wildlife.	• Take samples from exposed river bed or banks of river (if regularly inundated). • Use hand-held detectors to guide sampling • Report results as Bq/kg (dry weight).	• Take samples from predominant sediment type. • Obtain a sample, which is reasonable representative over a scale of up to 5-10 m. This may be achieved by selecting sampling positions from five points along the exposed river bed or bank at distance of 1 m apart. Samples may be bulked. • Collect surface sediment samples (0-1 cm) with flat hand shovel (or appropriate tool) over selected area.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight and prevent fusing of sample (e.g. oven dry 40-105^{o}C or freeze dry). (May need to analyse wet for volatile radionuclides). • Record dry/wet ratio. • Remove gravel component by sieving to <2 mm and discarding >2 mm fraction. • Ensure representative sub-sample is taken for analysis (for example, by grinding and coning and quartering).
	• ***Environmental indicator*** - To monitor the long-term concentrations. • ***Distribution*** – Examine areas of deposition/concentration.	• As above	• As above	• As above • May need to restrict grain size fraction (for example. sieve to <250 μm) or report factors which can influence concentrations (such as grain size, loss on ignition at 450^{o}C which is a good surrogate for grain size). Results may be normalised by these factors to reduce variability [Ref 8].

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Freshwater sediments (cont)	• ***Investigative/model check*** – To investigate the impact of historical discharges and check models against these discharges.	• This may require sampling over water in a boat. • Report results as Bq/kg (dry weight).	• Take core samples using an appropriate device. • Obtain a sample which is reasonably representative across the width of the river. This may be achieved with five core samples of 10 cm diameter taken equidistant across the river. • The depth of the core should enable the monitoring objectives to be achieved, but may be limited to 5-10 cm, if there is little sediment above the bedrock. It should be noted that longer cores can be affected by compression, with this being greatest near the (wetter) top. Account of this will need to be taken when preparing the core further. • Section core into slices which enable the monitoring objectives to be achieved. Cores are typically sectioned into 5-10 cm slices. Clean core sectioning tool (blade) between slices. • Sub-sample from centre of each core slice to reduce smearing. • Bulk the same sections of cores together as appropriate.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight and prevent fusing of sample (e.g. oven dry 40-105^{o}C or freeze dry). (May need to analyse wet for volatile radionuclides). • Record dry/wet ratio. • Remove gravel component by sieving to <2 mm and discarding >2 mm fraction. • Ensure representative sub-sample is taken for analysis (for example, by grinding and coning and quartering).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Road drain sediments (gully pots)	• ***Environmental indicator*** – To provide an indicator of authorised or unauthorised fugitive releases, land contamination and migration of contamination.	• Determine when gully pot last cleaned. • Report results as Bq/kg (dry weight).	• Check that drain is receiving water run-off. • Collect sediment sample with appropriate tool (such as a long handled trowel). • Arrange for cleaning of road drain post-sampling, to provide better information on timing of any contamination.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chilled at about 4°C or freeze). • Dry sample to constant weight and prevent fusing of sample (e.g. oven dry 40-105°C or freeze dry). (May need to analyse wet for volatile radionuclides). • Record dry/wet ratio. • Remove gravel, litter and so on by sieving to <2 mm and discarding >2 mm fraction. • Ensure representative sub-sample is taken for analysis (for example, by grinding and coning and quartering).
Leachate (landfill)	• ***Environmental indicator*** – To provide an indicator of land contamination and migration of contamination. • ***Critical group dose*** – To assess dose if leachate is disposed of to sewage treatment works and then into the environment.	• Detailed guidance on collection of samples from boreholes is provided in References 1 – 5. • Report results as Bq/l (for dissolved and particulate phases) and kg/l of particulate (if appropriate).	• Determine sample collection depth based on monitoring requirements. • Select collection apparatus (e.g. bailer or pump) – use pump only if content < 5% solid. Suction pumps are only recommended for depths of <8 m. A submersible pump is required for deeper boreholes. • Purge borehole (three borehole volumes). • Rinse collection apparatus and container with sample. • Collect representative sample. • Store the sample to prevent deterioration in transit to the lab (for example, in cool, dark conditions).	• Store samples at laboratory to minimise growth of algae and avoid degradation of sample (e.g. chill at about 4°C or freeze in the dark). • Filter samples through a 0.45 µm membrane and analyse filtrate and residue if the monitoring objective requires information on the partitioning between dissolved and particulate phases (e.g. migration of leachate into groundwater). • Ensure representative sub-sample is taken for analysis (for example, shake liquid samples).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Sewage/sludges	• ***Critical group dose*** **–** To assess dose to sewage treatment workers and other exposed groups as a result of disposal of sludge. • ***Environmental indicator*** **–** To check discharge of radioactivity into sewerage systems. • ***Model check*** – To check models for transfer of radionuclides to sludge.	• Report results as Bq/l or Bq/kg (dry weight) depending on water content.	• Collect sample in a container which minimises any offensive smell.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Dry sample to constant weight and prevent fusing of sample (e.g. oven dry 40-105^{o}C in a well ventilated oven or freeze dry). (May need to analyse wet for volatile radionuclides or if smell is too offensive to allow drying). • Record dry/wet ratio. • Ensure representative sub-sample is taken for analysis (for example, shake liquid samples).
Contaminated land	• ***Contamination*** – To characterise contamination on site.	• See guidance for site characterisation [Ref 12] and for aerial surveys [Ref 15].	-	-

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Drinking water (tap water)	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in drinking water. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated water. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in drinking water arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident.	• Determine appropriate sample container for radionuclide(s) to be sampled. • Decide upon whether you want mains tap water or the water from within the household pipework. • Record site location of sample. • Follow radon specific protocol if measuring for radon [Ref 13]. • Report results as Bq/l.	• Rinse collection apparatus and container with sample. • Take representative sample bearing in mind the need to allow tap to run for adequate time interval depending upon sample type requirement (household or mains water). • Collect water sample directly into the container. • Minimise radionuclide adsorption to container walls by adding a carrier or preservative to water as appropriate (dependent upon the radionuclide). • Store the sample to prevent deterioration in transit to the lab (for example in cool, dark conditions).	• Minimise growth of algae and avoid degradation of sample (for example, by keeping sample cool and in the dark during storage). • Do not filter sample. • Concentrate sample if needed (for example, through ion exchange or evaporation).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Drinking water (wells or groundwater - assumed to be local consumers direct from groundwater via borehole or spring)	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in drinking water. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated water. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in drinking water arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident.	• Detailed guidance on collection of groundwater samples is provided in References 1 – 5. • Determine appropriate sample container for radionuclide(s) to be sampled. • If used, confirm borehole is suitable for sampling and representative of the water consumed. • Record site location of sample. • Follow radon specific protocol if measuring for radon [Ref 13]. • Report results as Bq/l.	• Identify geochemical strata (water origin). • Select collection apparatus (e.g. bailer or pump) – use pump only if content < 5% solid. Suction pumps are only recommended for depths of <8 m. A submersible pump is required for deeper boreholes. • Purge borehole (three borehole volumes). • Rinse collection apparatus and container with sample. • Collect representative sample. • Minimise radionuclide adsorption to container walls by adding a carrier or preservative to water as appropriate (dependent upon the radionuclide). • Store the sample to prevent deterioration in transit to the lab (for example in cool, dark conditions).	• Keep sample cool (away from heat sources) and in the dark during storage. • Do not filter sample. • Concentrate sample if needed (for example, through ion exchange or evaporation).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Milk and milk products	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in terrestrial foodstuffs. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated foodstuffs. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in foodstuffs arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Distribution*** **–** Determine the spread of radionuclides through foodstuffs/the environment from radioactivity arising from routine authorised releases • ***Model check*** – Provide data that, along with other monitoring of soil, air and water, may be useful to check reported discharges and dispersion and transfer models.	• Two methods of preparation: either the analysis of the raw edible fraction (such as milk collected directly from the farm) or via culinary preparation (in the case of milk, this might mean sampling processed butter, milk and so on). • Report results as Bq/l. If results are reported as dry weight then the fresh:dry weight ratio should be provided.	• Rinse collection apparatus and container with sample (if milk). • Select a representative sample of the source material. Consider the area over which cattle have been grazing, if taken at the farm, how many animals should be sampled, sampling from the tanker and so on. • Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample). • Add carrier or preservative to milk as appropriate depending upon the radionuclide. • Store the sample to prevent deterioration in transit to the lab (for example, store in air tight containers, cool box).	• Select a representative sub-sample for analysis (for example, shake milk sample). • Concentrate sample if needed (for example, by evaporation, ion-exchange, freeze drying).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Cereal	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in terrestrial foodstuffs. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated foodstuffs. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in foodstuffs arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Distribution*** **–** Determine the spread of radionuclides through foodstuffs/the environment from radioactivity arising from routine authorised releases • ***Model check*** – Provide data that, along with other monitoring of soil, air and water, may be useful to check reported discharges and dispersion and transfer models.	• Prepare the raw edible fraction (such as mature grain) for analysis. Culinary preparation may need to be taken into account (in the case of cereal, this might mean sampling bread). • Approach outlined is for longer-lived radionuclides that will still exist by the time the food product is available for human consumption. • For the objective of understanding distribution in the field, analysis does not need to focus on mature grain and any stage of the crop may be sampled and analysed fresh and immediately to detect short-lived radionuclides. • Consider the need for local sampling versus retail sampling for national averages. • Report results as Bq/kg (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided.	• Identify cereal type. • Sample the material at an appropriate time (for example, as mature grain straight from the field or as grain that has been harvested). • Select a representative sample of the source material. When sampling in the field, consider the location and size of area to be sampled (for example, in the field collect sample from the ends of a W or X shaped sampling pattern). When sampling grain from sacks after harvesting, consider how many samples, which sacks and so on to sample. • Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample). • Store the sample to prevent deterioration in transit to the lab (for example, store in air tight containers).	• Store samples in lab to prevent deterioration (e.g. chill at about 4^{o}C or freeze) • Prepare samples to provide edible fraction (may require culinary preparation depending upon the objective). • Dry sample to constant weight (e.g. air dry, oven dry 40 – 105^{o}C, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/fresh ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sampled in mill or blender or blending fresh samples, Cone and quarter if appropriate).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Meat and meat products including wild or game foods such as hare, rabbit	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in terrestrial foodstuffs. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated foodstuffs. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in foodstuffs arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Distribution*** **–** Determine the spread of radionuclides through foodstuffs/the environment from radioactivity arising from routine authorised releases • ***Model check*** – Provide data that, along with other monitoring of soil, air and water, may be useful to check reported discharges and dispersion and transfer models.	• Prepare the raw edible fraction for analysis (for example, from a mature animal that would be sold commercially. Culinary preparation may need to be taken into account). • Approach outlined is for longer-lived radionuclides that will still exist by the time the food product is available for human consumption. • Consider the need for local sampling versus retail sampling for national averages. • Report results as Bq/kg (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided.	• Identify sample type and determine a representative cut/part of the animal (e.g. the thigh, neck etc to ensure select the edible fraction that would be consumed). • Select a representative sample noting that it may not be possible to be selective (e.g. some wild foods may be collected from road kills/natural deaths as opposed to culling). • Select sample(s) of muscle, liver and kidney as these cover the main sites of radionuclide accumulation and are all consumed in significant quantities. • Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample). • Store the sample to prevent deterioration in transit to the lab (e.g. store in air tight containers).	• Store samples in lab to prevent deterioration (e.g. chill at about 4^{o}C or freeze). • Prepare samples to provide edible fraction (may require culinary preparation depending upon the objective). • Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry). Analyse fresh if detection limits can be achieved and a representative sub-sample can be taken; or if volatile radionuclides are present). • Record dry/fresh ratio. • Select a representative sub-sample for analysis (e.g. by homogenising dry sample in mill or blender; or mincing fresh sample. Cone and quarter if appropriate).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Poultry, eggs and honey including wild or game foods such as goose, mallard, partridge, pheasant, pigeon, teal	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in terrestrial foodstuffs. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated foodstuffs. • ***Environmental indicator*** - monitor the long-term behaviour of radionuclides in foodstuffs arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Distribution*** **–** Determine the spread of radionuclides through foodstuffs/the environment from radioactivity arising from routine authorised releases • ***Model check*** – Provide data that, along with other monitoring of soil, air and water, may be useful to check reported discharges and dispersion and transfer models.	• Prepare the raw edible fraction for analysis (e.g. from a mature bird that would be sold commercially). Culinary preparation may need to be taken into account. • Approach outlined is for longer lived radionuclides that will still exist by the time the food product is available for human consumption. • Consider the need for local sampling versus retail sampling for national averages • Report results as Bq/kg (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided.	• Identify sample type and determine a representative cut/part of the food stuff (for example, the thigh or breast for the bird to ensure selection of the edible fraction). • Select a representative sample noting that it may not be possible to be selective (for example, some wild foods may be collected from road kills/natural deaths as opposed to culling) • Select sample(s) of muscle, liver and kidney as these cover the main sites of radionuclide accumulation and are all consumed in significant quantities. • Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample). • Store the sample to prevent deterioration in transit to the lab (for example, store in air tight containers).	• Store samples in lab to prevent deterioration (e.g. chill at about 4^{o}C or freeze). • Prepare samples to provide edible fraction (may require culinary preparation depending upon the objective). • Dry sample to constant weight (e.g. air dry, oven dry 40 – 105^{o}C, freeze-dry). Analyse fresh if detection limits can be achieved and a representative sub-sample can be taken; or if volatile radionuclides are present. • Record dry/fresh ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blender; blending/whisking/stirring honey/eggs; or mincing fresh sample. Cone and quarter if appropriate).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Fruit and vegetables including wild foods such as: apple, bilberry, blackberry, cherry, chestnut, chive, cobnut/hazelnut, crab apple, damson, dandelion, elderberry, elderflower, garlic, hawthorn berry, horseradish, mayflower, mint, mushroom, nettle, peppermint, plum, raspberry, rose hip, rowanberry, sloe, strawberry, watercress	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in terrestrial foodstuffs. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated foodstuffs. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in foodstuffs arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Distribution*** **–** Determine the spread of radionuclides through foodstuffs/the environment from radioactivity arising from routine authorised releases • ***Model check*** – Provide data that, along with other monitoring of soil, air and water, may be useful to check reported discharges and dispersion and transfer models.	• Prepare the raw edible fraction (for example, mature fruit/vegetable as may be sold commercially) for analysis. Culinary preparation may need to be taken into account. • Approach outlined is for longer-lived radionuclides that will still exist by the time the food product is available for human consumption. • Consider the need for local sampling versus retail sampling for national averages. • Report results as Bq/kg (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided.	• Identify sample type. • Collect sample and remove any extraneous material. • Select a representative sample of the source material. When sampling in the field, consider the location and size of area to be sampled (for example, collect sample from the ends of a W or X shaped sampling pattern). When sampling sacks/boxes after harvesting, how many samples, which sacks/boxes and so on to sample. For wild foods, consider number of plants sampled (for example, for blackberries and other hedgerow species, sample from along a 10 m length of hedge). • Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample). • Store the sample to prevent deterioration in transit to the lab (for example, store in air tight containers).	• Wash in water to remove soil (vegetables) and chemicals (fruit). • Store samples in lab to prevent deterioration (e.g. chill at about 4°C or freeze) • Prepare samples to provide edible fraction (may require culinary preparation depending upon the objective). • Dry sample to constant weight (e.g. air dry oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/fresh ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Freshwater fish and crustacean	• ***Critical group dose*** **–** To monitor the radiological exposure pathway from consumption of radioactivity in terrestrial foodstuffs. • ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases, contaminated foodstuffs. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in foodstuffs arising from routine authorised releases. • ***Baseline*** – To provide a baseline in the event of a radiological incident. • ***Distribution*** **–** Determine the spread of radionuclides through foodstuffs/the environment from radioactivity arising from routine authorised releases • ***Model check*** – Provide data that, along with other monitoring of soil, air and water, may be useful to check reported discharges and dispersion and transfer models.	• Select species to meet monitoring objective (for example, stage of growth, availability). • Report results as Bq/kg (fresh weight).	• Correctly identify species caught by net or line. • Store samples during transport to prevent deterioration.	• Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4^{o}C or freeze). • Prepare the raw edible fraction for analysis. Culinary preparation may need to be taken into account. • Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides. • Record dry/wet ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Wildlife (all species but not domesticated species such as cattle, sheep)	• ***Wildlife*** – To determine the radiological exposure to wildlife. • ***Environmental indicator*** - Monitor the long-term behaviour of radionuclides in wildlife arising from routine authorised releases.	• Report results as Bq/kg (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided.	• Select species for required sampling. • Correctly identify species and collect road kill or cull if needed (bearing in mind the legal protection afforded to some species). • Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample). • Store the sample to prevent deterioration in transit to the lab (for example, store in air tight container, cool box).	• Store samples in lab to prevent deterioration (e.g. chill at about 4^{o}C or freeze) • Prepare samples as whole (including entrails) OR prepare specific portion of sample (such as the thyroid). • Record weights of parts required for analysis and for discarded parts. • Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry). Analyse fresh if detection limits can be achieved and a representative sub-sample can be taken; or if volatile radionuclides are present. • Record dry/fresh ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blender; or mincing fresh sample. Cone and quarter if appropriate).

Table 4b: Continued – Terrestrial monitoring

Sample type	Objective	General	Sampling/Monitoring	Sample preparation
Wildlife (cont) (all species but not domesticated species such as cattle, sheep)	• ***Reassurance*** **–** Provide reassurance through the detection and monitoring of abnormal releases. • ***Contamination*** - To determine the potential for wildlife to spread radionuclide contamination.	• This is likely to be ad hoc monitoring or based on sample availability rather than routine targeted sampling. • Report results as Bq/kg (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided.	• Select species for required sampling. • Correctly identify species and collect road kill or cull if needed (bearing in mind the legal protection afforded to some species) or sample faeces or live monitor. If faeces collected then guidance on storage and preparation of sewage sludge should be considered. • Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample). • Store the sample to prevent deterioration in transit to the lab (for example, store in air tight containers, cool box).	• Store samples in lab to prevent deterioration (e.g. chill at about 4^{o}C or freeze). • Prepare samples as whole (including entrails) OR prepare specific portion of sample (such as feathers). • Record weights of parts required for analysis and for discarded parts. • Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry). Analyse fresh if detection limits can be achieved and a representative sub-sample can be taken; or if volatile radionuclides are present. • Record dry/fresh ratio. • Select a representative sub-sample for analysis (for example, by homogenising dry sample in mill or blender; or mincing fresh sample. Cone and quarter if appropriate).

Appendix A – Initial guidance for workshop

This appendix contains the following preliminary documents presented to the workshop:

- Table A1a: Analysis of costs, risks/weaknesses and benefits/strengths – Terrestrial sampling/monitoring
- Table A1b: Analysis of costs, risks/weaknesses and benefits/strengths – Inter-tidal sampling/monitoring
- Table A2: Best practice environmental monitoring guidance, which was used as the basis for discussion at the workshop.

Table A1a: Costs, risks/weaknesses and benefits/strengths of alternative approaches (presented to workshop) – Terrestrial monitoring

Sample Type	Objective	Comparison	Costs	Risks/Weaknesses	Benefits/Strengths
Dose rate monitoring	Dose Background for incidents Model validation Reassurance Trends	TLDs	• TLD device • Analytical costs • Lab staff time	• Uncertainty due to environmental damage, vandalism and contamination • Relatively expensive (staff/analytical) for frequent surveys • Delayed qualitative results • Uncertainty in device until analysis completed	• Cheaper for infrequent surveys • Less staff time • Pre-calibrated from manufacturer • No maintenance or breakdown costs
		Mini 6-80	• Detectors • Routine maintenance and calibration • Repairs • Field staff time	• Instrument failure (mechanical or operation in field)	• Quick quantitative results on site • Established methodology
Air passive shades and HVAS/MVAS	Dose Model validation Reassurance Trends Sea-to-land transfer Abnormal releases	Air passive shades	• Specialist material and frames • Staff collection time	• Damage to cloths and frames (weather and vandalism) • Delayed qualitative results • Cannot derive air concentrations	• Cheaper start-up costs • Low maintenance • No breakdown costs
		HVAS/MVAS	• HVAS/MVAS sampler • Routine maintenance and calibration • Repairs • Field staff time	• Failure of instrument (mechanical or weather) • Continuous power source required • Semi-quantitative results possible (due to large particles) • Inlet and wall losses produces errors in results • Delayed results	• Quantitative results

Table A1a: Continued – Terrestrial monitoring

Sample Type	Objective	Comparison	Costs	Risks/Weaknesses	Benefits/Strengths
Wet, dry, total deposition	Dose Model validation Trends Abnormal releases	Field laboratory gamma spectrometry	• Detector • Routine maintenance and calibration • Repairs • Field staff time	• Failure of instrument (mechanical or weather) • Need for a continuous power source • Damage to collection apparatus (weather and vandalism)	• Quick semi-quantitative results on site • Established methodology
		Lab gamma spectrometry	• Detector • Routine maintenance and calibration • Repairs • Lab staff time	• Failure of instrument (mechanical) • No results on site	• Quantitative results • More accurate results due to further preparation before counting • Likely to have more than one detector • Established methodology
Soil	Dose Background for incidents Model validation Trends Abnormal releases	Cores and field laboratory gamma spectrometry	• Detector • Routine maintenance and calibration • Repairs • Field staff time	• Failure of instrument (mechanical or weather) • Need for a continuous power source	• Quick semi-quantitative results on site • Established methodology
		In situ gamma spectrometry	• Detector • Routine maintenance and calibration • Repairs • Field staff time	• Failure of instrument (mechanical or weather) • Need for a continuous power source • Need to establish calibration	• Once calibrated, no need to take soil samples and hence no preparation and laboratory analytical costs • Better integration of concentration over a wider area and depth
		Cores and lab gamma spectrometry	• Detector • Routine maintenance and calibration • Repairs • Lab staff time	• Failure of instrument (mechanical) • No results on site	• Quantitative results • More accurate results due to further preparation before counting • Likely to have more than one detector • Established methodology

Table A1a: Continued – Terrestrial monitoring

Sample Type	Objective	Comparison	Costs	Risk/ Weaknesses	Benefits/ Strengths
Groundwater	Dose Contamination Trends	Surface sampling	• Collection materials • Field staff time	• Surface layer results only	• Quantitative results
		Depth	• Pumps • Routine maintenance and calibration • Repairs • Field staff time	• Failure of pump (mechanical or clogging with suspended matter	• Quantitative results • Depth profile with results
Freshwater sediments	Dose Trends Model validation	In situ gamma spectrometry	• Detector • Routine maintenance and calibration • Repairs • Field staff time	• Failure of instrument (mechanical or weather) • Need for a continuous power source • Need to establish calibration	• Once calibrated, no need to take soil samples and hence no preparation and laboratory analytical costs • Better integration of concentration over a wider area and depth
		Grab or coring	• Grab or corers • Routine maintenance and repairs • Possible hire/purchase of a suitable vessel • Field staff time	• Failure of grab or corer • Adverse weather conditions for vessel • Penetration of grab/corer of sand/gravel	• Quantitative results • Depth profile with results
Contaminated land	Dose Contamination Trends Removal of hot particles	Foot surveys	• Geiger-Muller detector • Routine maintenance and calibration • Repairs • Field staff time	• Failure of detector (mechanical or detector window being punctured by ground debris) • Length of time taken for survey may be substantial	• Rapid qualitative data • Detection of 'hot spots' • Cheap detectors

Sample Type	Objective	Comparison	Costs	Risk/ Weaknesses	Benefits/ Strengths
		Vehicle surveys	• NaI (Tl) detectors and attachment mounts/brackets for vehicles • Routine maintenance and calibration • Repairs (instruments/ vehicles) • Hire/purchase of vehicles • Field staff time	• Failure of detectors and vehicles • Ability of vehicle to traverse difficult terrain • Not carried out routinely nor established methodology	• Effective and efficient in covering larger areas and in less time • Semi-quantitative results

Table A1b: Costs, risks/weaknesses and benefits/strengths of alternative approaches (presented to workshop) – Inter-tidal monitoring

Sample Type		Comparison	Costs	Risks/Weaknesses	Benefits/Strengths
Estuary/ coastal contamination monitoring - small particles	Dose Contamination Trends Removal of hot particles	Foot surveys	• Geiger-Muller detector • Routine maintenance and calibration • Repairs • Field staff time	• Failure of detector (mechanical or detector window being punctured by ground debris) • Length of time taken for survey may be substantial	• Rapid qualitative data • Detection of 'hot spots' • Cheap detectors
		Vehicle surveys	• NaI (Tl) detectors and attachment mounts/brackets for vehicles • Routine maintenance and calibration • Repairs (instruments/vehicles) • Hire/purchase of vehicles • Field staff time	• Failure of detectors and vehicles • Ability of vehicle to traverse difficult terrain • Not carried out routinely nor established methodology	• Effective and efficient in covering larger areas and in less time • Semi-quantitative results
Estuary dose rate	Dose Model validation Reassurance Trends	TLDs	• TLD device • Analytical costs • Lab staff time	• Uncertainty due to environmental damage, vandalism and contamination • Relatively expensive (staff/analytical) for frequent surveys • Delayed qualitative results • Uncertainty in device until analysis completed	• Cheaper for infrequent surveys • Less staff time • Pre-calibrated from manufacturer • No maintenance or breakdown costs

Sample Type		Comparison	Costs	Risks/Weaknesses	Benefits/Strengths
		Mini 6-80	• Detectors • Routine maintenance and calibration • Repairs • Field staff time	• Instrument failure (mechanical or operation in field)	• Quick quantitative results on site • Established methodology

Table A1b: Continued – Inter-tidal monitoring

Sample Type		Comparison	Costs	Risk/ Weaknesses	Benefits/ Strengths
Sediment	Historical discharges Model validation	In situ gamma spectrometry	• Detector • Routine maintenance and calibration • Repairs • Field staff time	• Failure of instrument (mechanical or weather) • Need for a continuous power source • Need to establish calibration	• Once calibrated, no need to take soil samples and hence no preparation and laboratory analytical costs • Better integration of concentration over a wider area and depth
		Sediment cores	• Grab or corers • Routine maintenance and repairs • Possible hire/purchase of a suitable vessel • Field staff time	• Failure of grab or corer • Adverse weather conditions for vessel • Penetration of grab/corer of sand/gravel	• Quantitative results • Depth profile with results

Table A2: Best practice environmental monitoring guidance (presented to workshop)

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Air passive shades (APS) and High/Medium Volume Air Sampling (HVAS / MVAS)	To monitor the long-term concentrations of radionuclides in air from routine releases, with particular emphasis on those radionuclides for which the inhalation exposure pathway may be significant (such as actinides). To validate reported discharges and air dispersion modelling. To provide information on sea-to-land transfer of radionuclides for coastal sites. Results reported as Bq/m^3	APS • Select monitoring grid of ~ 1 km and increments of 5 km, up to 20 km, in all land directions. • Construct monitoring support and attach shade. • Monitor monthly. OR HVAS/MVAS • Select monitoring point, within ~ 1 km of source in open space. • Secure power supply. • Sample for 24 hours.	**Preparation for fieldwork** HVAS/MVAS • Calibrate instrument to determine air volume.
	To detect abnormal releases. To provide information on sea-to-land transfer of radionuclides for coastal sites. Results reported as Bq/m^3 or Bq/shade	APS • Select monitoring grid of ~ 1 km and increments of 5 km, up to 20 km, in all land directions. • Construct monitoring support and attach shade. • Monitor daily. OR HVAS/MVAS • Select monitoring point, within ~ 1 km of source in open space • Secure power supply. • Sample for between one and 24 hours.	**Preparation for fieldwork** HVAS/MVAS • Calibrate instrument to determine air volume.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Contaminated land	To determine the extent of contamination and assessment of dose using general surveys. Results reported as counts/s	• Identify substrate type and weather conditions. • Identify transects 5 m apart. • Monitor area using a probe with a Geiger-Muller detector, just above the surface, sweep at no more than 0.5 m/s. • Continue measurements above surface at fixed points along transects. • Determine integrated count over time of transect.	**Preparation for fieldwork** • Calibrate instrument to known standard.
	To detect and remove any hot particles deposited on land. Results reported as µSv/h (for each particle)	By foot: • Following general survey, spot count (15s) suspected contamination above ground surface, using Berthold LB 122 (or similar). • Collect hot spots using surface scrapes into suitable containers. • Continue to monitor after surface scrapes to remove small particles at depth. By vehicle: • Monitor using four independent NaI (Tl) detectors, vehicle/detectors travel at 1m/s, and count for 1s, 20 cm above ground. • Travel the area using sweeps - no more than 50cm apart. • Collect hot spots using surface scrapes into suitable containers. • Continue to monitor after surface scrapes to remove small particles at depth.	**Preparation for fieldwork** • Calibrate instrument to known standard.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Dose rate monitoring	To provide measurements of external radiation dose from airborne and deposited radionuclides, and direct radiation. Close to nuclear establishments, there may also be a significant contribution due to direct radiation (shine) from the site and this monitoring therefore provides a measure of total external dose to the most exposed (critical) population groups. Routine monitoring also provides reference levels in the event of a radiological incident. (TLD) Results reported as µSv/h	• Determine sampling position and timescale for measurements.	• Ensure TLDs are calibrated to a known standard.
	To provide measurements of external radiation dose from airborne and deposited radionuclides, and direct radiation. Close to nuclear establishments, there may also be a significant contribution due to direct radiation (shine) from the site and this monitoring therefore provides a measure of total external dose to the most exposed (critical) population groups. Routine monitoring also provides reference levels in the event of a radiological incident. (Mini 6-80) Results reported as µGy/h	• Identify substrate type. • Choose location away from walls, trees, hedges and roads. • Set up detector in a vertical position, with its centre 1m above the ground. • Measure spot dose rate using Mini 6-80 instruments (or similar) for 600s. • Operator should stand at least 10m from detector to prevent effects of shielding. • Carry out duplicate counts of 600s. • Carry out measurements at two locations at a distance of 10m apart.	• Calibrate instrument to known standard.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Freshwater sediments	To provide validation of modelling. Report results as Bq/kg (dry weight).	**For over water sampling**: • Ensure safe access. • Identify sediment type. • Use coring device or grab sampler to obtain sediment sample (50 cm deep). • Collect five core samples at equidistance across river. • Section core into 5-10 cm slices, clean core sectioning tool (blade) between slices. • Sub-sample from centre of each core slice to reduce smearing. • Store sub-samples in suitable containers. • Keep chilled at 2°C.	• Oven dry (40°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise by sieving (< 500 µm) or crushing. • Further prepare sample dependent upon analyses required.
	To determine the potential source of exposure through inhalation and inadvertent ingestion during recreational activities. Report results as Bq/kg (dry weight).	For exposure from river bed or banks of river: • Ensure safe access. • Identify sediment type. • Select sampling positions from five points, ideally in an X shape, within a circle of 4 m in diameter. • Collect surface sediment samples (0-1 cm) with flat hand shovel (or appropriate tool) over selected area. • Keep chilled at 2°C.	• Oven dry (40°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise by sieving (< 500 µm) or crushing. • Further prepare sample dependent upon analyses required.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Grass/ Herbage	To monitor food sources for livestock that, in turn, provide products for human consumption (a particularly important exposure pathway being milk). The data may also be used to validate reported discharges and results from environmental transfer modelling. To detect abnormal releases; these materials provide a more sensitive indicator than milk since animals may graze over relatively large areas. Report results as Bq/kg (wet weight) and Bq/m^2	• Avoid cross contamination by collector treading on sampling area. • Record area where quadrates are placed. • Select three samples to be taken in a quadrate (0.25 m^2). • Trim sample approx. 10 mm above soil surface with shears (or similar) and collect samples (exclude non-herbage material). • Keep sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Leachate (landfill)	To provide an indicator of land contamination and migration of contamination. Report results as Bq/l	• Determine drainage layers (water origin). • Select collection apparatus – weighted plastic bucket or pump – use pump only if content < 5% solid. If sample depth is < 8 m, use a suction pump, if > 8 m, use a submersible electric pump. • Rinse collection apparatus and container with sample. • Collect sample.	• Keep sample cool (away from heat sources) and in the dark during storage. • Filter samples through a 0.45 µm membrane (analysis dependent). • Retain membrane to determine particulate fraction. • Preserve with nitric acid for long storage (analysis dependent). • Analyse ASAP.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Road drain sediments (gully pots)	To provide an indicator of fugitive releases, land contamination and migration of contamination. Report results as Bq/kg (dry weight).	• Check that drain is receiving water run-off. • Identify sediment type. • Collect surface sediment samples (0-1 cm) with flat hand shovel (or appropriate tool) over surface of gully pot, if sediment is exposed. Collect sediment sample using a long handled sampling trowel (or appropriate tool) if sediment is not exposed. • Keep chilled at 2°C.	• Oven dry (40°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise by sieving (< 500 µm) or crushing. • Further prepare sample dependent upon analyses required.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Sewage/ sludges	To assess dose. To monitor authorised and unauthorised discharge of radioactivity into sewerage systems from non-nuclear sites. To validate dose models. Report results as Bq/kg (dry weight) or Bq/l depending on water content.	• Address health and safety issues for collectors and analysts. • Select collection apparatus (use tap if available or weighted plastic bucket if content > 5% solid for liquids or suction pump if content < 5% solid for liquids i.e. sewage. A spade for thickened sludge. • Rinse collection apparatus and container with sample, if liquid. • Collect sample. • Keep sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• For liquid samples, add H_2O_2 to solubilise particles. Analyse ASAP. • Oven dry (60°C) solid samples to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Soil	To monitor part of environmental transfer pathway to milk. Root zone (the top few centimetres is the relevant zone). Potentially less variability than grass, thus better long-term measure of environmental quality (laboratory gamma spectrometry. Report results as Bq/kg (dry weight).	• Select location for five root zone samples in an X shape, within a circle of 10 m diameter. • Remove surface litter and overlying vegetation. • Using a turf cutter, extract a 10 cm x 15 cm x 2 cm sample. • Trim remaining surface vegetation off with a knife. • Collect each sample into a container. • Keep chilled at 2°C.	• Oven dry (40°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise by sieving (< 500 µm) or crushing. • Further prepare sample dependent upon analyses required.
	To enable the measurements of total deposition of short-lived radionuclides to be made. Important background measurement in case of incident (mobile gamma spectrometry). Report results as Bq/m^2.	• Select location for five cores in an X shape, within a circle of 10 m diameter. • Remove surface litter and overlying vegetation. • Using a stainless steel coring device (10 cm diameter, 50 cm depth), extract cores. • Section core into 5-10 cm slices, clean sectioning tool (blade) between slices. • Sub-sample from centre of each core slice to reduce smearing • Store sub-samples in suitable containers. • Keep chilled at 2°C. • Record area of cores.	**Preparation for fieldwork** • Calibrate instrument to known standard. **Preparation for analysis** • Pre-prepare sample in readiness to pack a standard geometry (for example, remove stones out of soil). • Pack a standard geometry container for in situ gamma counting.

Terrestrial non-food sample type

Sample type	Objective	Sampling	Preparation
Wet, dry, total deposition	To monitor the long-term deposition of radionuclides from routine releases and to provide field data to validate reported discharges and air dispersion and deposition modelling (in situ gamma spectrometry). Report results as Bq/m^2 or µGy/h	Deposition (excluding cosmic): • Record details about the site (e.g. a description of the weather conditions). • Identify sampling position. • Set up in situ gamma spectrometer with crystal (facing downwards) supported at 1 m above the ground, with a view of > 10 m radius. • Count for 20 minutes. Total deposition (including cosmic) and validation of in situ gamma spectrometry: • Set up detector (Mini 6-80 instruments or similar) in a vertical position, with its centre 1 m above the ground. • Measure spot dose rate for 600 seconds. • Operator should stand at least 10 m from detector to prevent effects of shielding. • Carry out duplicate counts of 600 seconds.	**Preparation for fieldwork** • Calibrate instruments to known standard.
	To monitor the long-term deposition of radionuclides from routine releases and to provide field data to validate reported discharges and air dispersion and deposition modelling (laboratory gamma spectrometry) Report results as Bq/m^2 /day or Bq/m^2/s or Bq/l/day	• Record details about the site (e.g. a description of the weather conditions). • Identify sample. • Choose appropriate collection apparatus depending upon sample matrix (such as frisbee gauge, rain gauge). • Use collection time of one month (or less if incident occurs). • Determine quantity (volume/mass) of deposition. • Transfer sample into an air tight container (to prevent deterioration). • Keep chilled at 2°C.	**Preparation for liquids** • Keep sample cool (away from heat sources) and in the dark during storage. • Do not filter sample, add H_2O_2 to solubilise particles. • Analyse ASAP. **Preparation for solids** • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Cereal	To monitor secondary food radiological exposure pathways. Report results as Bq/kg (wet weight)	• Identify cereal type. • Collect sample in air tight container (to prevent deterioration).	• Prepare samples as per culinary use to provide edible fraction. • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Sub-sample for analysis by coning and quartering. • Further prepare sample dependent upon analyses required.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Drinking water (tap water)	To monitor secondary consumption radiological exposure pathway. Report results as Bq/l	• Rinse collection apparatus and container with sample. • Allow tap to run for 10 seconds. • Collect water sample.	• Keep sample cool (away from heat sources) and in the dark during storage. • Do not filter sample, add H_2O_2 to solubilise particles. • Analyse ASAP.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Eggs, game and honey	To monitor secondary food radiological exposure pathways. Report results as Bq/kg (fresh weight)	• Identify/select choice of retail meat from thigh or breast (game) – collect in suitable clean airtight container (game, eggs and honey). • Keep chilled at 2°C.	• Prepare samples as per culinary use to provide edible fraction. • Homogenise egg contents by whisking, mincing for game and stirring for honey. • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides) • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Freshwater (lakes, rivers and streams)	To monitor secondary consumption radiological exposure pathways from rivers, lakes and streams. To indicate a measure of abnormal releases, land contamination. To provide validation of modelling. Report results as Bq/l	• Rinse collection apparatus and container with sample. Discard downstream of sampling location. • Collect water (use water submersible pump for large volume samples or bucket/carboy for small volume samples).	• Keep sample cool (away from heat sources) and in the dark during storage. • Filter samples through a 0.45 µm membrane (analysis dependent). • Retain membrane to determine particulate fraction. • Preserve with nitric acid for long storage (analysis dependent). • Analyse ASAP.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Fruit and vegetables	To monitor secondary food radiological exposure pathways and to validate dose models. Report results as Bq/kg (wet weight).	• Collect sample and remove any extraneous material. • Wash in water to remove soil (vegetables) and chemicals (fruit). • Keep sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Prepare samples as per culinary use to provide edible fraction. • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Groundwater	To monitor migration of radionuclides from authorised and unauthorised disposals. Indicator of land contamination and migration of contamination. Report results as Bq/l	• Identify geochemical strata (water origin). • Purge groundwater. • Rinse collection apparatus and container with sample. • Collect water (use water submersible pump for large volume samples. Use suction pump < 8 m depth, submersible electric pump > 8 m.	• Keep sample cool (away from heat sources) and in the dark during storage. • Filter samples through a 0.45 µm membrane (analysis dependent). • Retain membrane to determine particulate fraction. • Preserve with nitric acid for long storage (analysis dependent). • Analyse ASAP.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Meat and meat products	To monitor secondary food radiological exposure pathways and to validate dose models. Animals that have recently grazed at locations of interest, particularly in summer. Report results as Bq/kg (fresh weight).	• Identify/select choice of retail meat from thigh, neck or liver (sheep and cows) • Collect sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Prepare samples as per culinary use to provide edible fraction. • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Milk	To determine important potential exposure pathway. Animals graze over relatively large areas and thus spatial averaging is inherent in sampling this material (c.f. grass and soil sampled at fixed locations). Report results as Bq/l	• Rinse collection apparatus and container with sample. • Keep chilled at 2°C.	• Prepare samples as whole by shaking to ensure homogeneity • Further prepare sample dependent upon analyses required.

Terrestrial food sample type

Sample type	Objective	Sampling	Preparation
Wildlife (such as feral pigeons and gulls)	To determine the exposure pathway through consumption of wildlife incorporating radionuclides. Report results as Bq/kg (fresh weight)	• Select species for required sampling. • Correctly identify species and cull. • Collect sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Prepare samples as per culinary use to provide edible fraction. • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.
	To determine the potential for wildlife to spread radionuclide contamination. To determine whole body concentrations from which dose predictions can be made for the organisms. Report results as Bq/kg (fresh weight)	• Select species for required sampling. • Correctly identify species from finds of dead birds. • Collect sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Prepare samples as whole (including entrails) OR prepare specific portion of sample (such as the thyroid). • Record weights of parts required for analysis and for discarded parts. • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Contamination monitoring	To establish β/γ contact dose rate to enable dose to skin to be assessed. Results reported as µSv/h	• Identify samples type. • Measure 10 spot dose rate readings (15s) across surface using Berthold LB 122 (or similar) with shield on (γ only) and with shield off (β & γ).	**Preparation for fieldwork** • Calibrate instrument to known standard.

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Estuary/ coastal dose rate monitoring	To provide measurements of external radiation dose from radionuclides incorporated in sediments and to validate models. Results reported as μGy/h over sediment type (including natural background)	• Identify sediment type and weather conditions. • Set up detector in a vertical position, with its centre 1m above the ground. • Measure spot dose rate using Mini 6-80 instruments (or similar) for 600s. • Operator should stand at least 10m from detector to prevent effects of shielding. • Carry out duplicate counts of 600s. • Carry out measurements at two locations at a distance of 10m apart.	**Preparation for fieldwork** • Calibrate instrument to known standard.
	To establish β/γ contact dose rate (such as on fishing nets) to enable dose to skin to be assessed. Results reported as μSv/h	• Identify sediment type and weather conditions. • Measure 10 spot dose rate readings (15s) across surface using Berthold LB 122 (or similar) with shield on (γ only) and with shield off (β & γ).	**Preparation for fieldwork** • Calibrate instrument to known standard.

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Estuary/ coastal contamination monitoring - general contamination	To determine the extent of contamination using general surveys. Results reported as counts/s	• Identify substrate type and weather conditions. • Identify transects 5 m apart. • Monitor area using a probe with a Geiger-Muller detector, just above the surface, sweep at no more than 0.5 m/s. • Continue measurements above surface at fixed points along transects. • Determine integrated count over time of transect.	**Preparation for fieldwork** • Calibrate instrument to known standard.

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Estuary/coastal sediments	To monitor the impact of recent discharges on environmental concentrations. To determine the potential source of exposure through inhalation and inadvertent ingestion during recreational activities. Report results as Bq/kg (dry weight).	• Allow for tide times and safe access • Locate fine-grained sediment and ensure depositional environment OR the predominant sediment type (if no fine-grained sediment available). • Collect five surface sediment samples (0-1 cm) with flat hand shovel (or appropriate tool) from point in an X shape within a circle of 4 m diameter. • Keep chilled at 2°C.	• Oven dry (40°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise by sieving (< 500 µm) or crushing. • Further prepare sample dependent upon analyses required.
	To provide validation of historical discharges and sea dispersion modelling. Report results as Bq/kg (dry weight).	• Allow for tide times and safe access. • Identify sample location with depositional history. • Use coring device (able to withstand saline environment) to obtain core sample (50 cm depth). Take five cores from points in an X shape within a circle of 4m. • Section core into 5-10 cm slices, clean sectioning tool (blade) between slices. • Sub-sample from centre of each core slice to reduce smearing • Store sub-samples in suitable containers. • Keep chilled at 2°C.	• Oven dry (40°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise by sieving (< 500 µm) or crushing. • Further prepare sample dependent upon analyses required.

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Estuary/ coastal contamination monitoring – small particles	To detect and remove any hot particles deposited on beaches (by foot). Results reported as µSv/h (for each particle)	• Allow for tide times and safe access. • Monitor strandline (order of importance; most recent tide-line, the extreme high water mark and wind blown debris above the extreme high water mark) using a probe with a Geiger-Muller detector, count above ground surface in sweeping motion to detect increase in counts. • Collect hot spots using surface scrapes into suitable containers. • Continue to monitor after surface scrapes to remove small particles at depth.	**Preparation for fieldwork** • Calibrate instrument to known standard.
	To detect and remove any hot particles deposited on beaches (by vehicle). Results reported as µSv/h (for each particle)	• Allow for tide times and safe access. • Monitor using four independent NaI (Tl) detectors, vehicle/detectors travel at 1m/s, and count for 1s, 20 cm above ground. • Travel the area using sweeps - no more than 50cm apart. • Collect hot spots using surface scrapes into suitable containers. • Continue to monitor after surface scrapes to remove small particles at depth.	**Preparation for fieldwork** • Calibrate instrument to known standard.

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Fish	To determine the exposure pathway through consumption of fish incorporating radionuclides. Report results as Bq/kg (wet weight).	• Select species for required sampling. • Correctly identify species caught by net or line. • Collect sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Prepare samples as per culinary use to provide edible fraction. • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.
	To determine the potential for fish to disperse radionuclide contamination. To determine whole body concentrations from which dose predictions can be made. Report results as Bq/kg (wet weight).	• Select species for required sampling. • Correctly identify species caught by net or line. • Collect sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Prepare samples as whole (including entrails) OR prepare specific portion of sample (such as the thyroid). • Record weights of parts required for analysis and for discarded parts (to allow for total body burden). • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Seawater	To provide precursory information with regard to incorporation of radionuclides in sediment, fish and shellfish. To provide validation of reported discharges and sea dispersion modelling. To provide an inventory in a given area. Report results as Bq/l	• Allow for tide times and safe access (for beach collection). • Rinse collection apparatus and container with sample. • Collect water (use water submersible pump for large volume samples or bucket/carboy for small volume samples).	• Keep sample cool (away from heat sources) and in the dark during storage. • Filter samples through a 0.45 µm membrane (analysis dependent). • Retain membrane to determine particulate fraction. • Preserve with nitric acid for long storage (analysis dependent). • Analyse ASAP.

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Seaweed	To indicate a measure of response to environmental change and hence to provide a good indicator of recent discharges, particularly for more soluble radionuclides. Consider seasonal (annual) cycle on sampling strategy. Report results as Bq/kg (wet weight).	• Allow for tide times and safe access (for beach collection). • Correctly identify single species (including hybrids). • Collect and trim recent growth from fronds. • Wash in water to remove particulate. • Keep sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Oven dry (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.
	To assess dose to exposed population groups from consumption as food. Report results as Bq/kg (wet weight).	• Allow for tide times and safe access (for beach collection). • Correctly identify food species. • Collect fresh seaweed (recent growth) or parts used for food according to local practice. • Wash in water to remove particulate. • Keep sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Oven dry (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.
	To assess dose from use of seaweed as compost and consumption of food. Report results as Bq/kg (wet weight).	• Allow for tide times and safe access (for beach collection). • Correctly identify the species used for the compost and collect sample (according to local practice). • Keep sample in airtight container (to prevent deterioration). • Keep chilled at 2°C.	• Oven dry (60°C) to constant weight. (Analyse wet for volatile radionuclides) • Homogenise sample in mill or blender. • Record dry/wet ratio. • Further prepare sample dependent upon analyses required

Inter-tidal sample type

Sample type	Objective	Sampling	Preparation
Shellfish	To determine the exposure pathway through consumption of crustaceans and molluscs incorporating radionuclides. Report results as Bq/kg (wet weight).	• Allow for tide times. • Select species for required sampling. • Correctly identify species and collect by hand sampling/digging or using pots (mollusc and crustacean). Do not depurate. • Collect sample in a suitable container. • Keep chilled at 2°C.	• Prepare samples as per culinary use to provide edible fraction either raw or by boiling in artificial seawater. • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.
	To determine the potential for crustaceans and molluscs to disperse radionuclide contamination. To determine whole body activity concentrations from which dose predictions can be made. Report results as Bq/kg (wet weight).	• Allow for tide times. • Select species for required sampling. • Correctly identify species and collect by hand sampling/digging or using pots (mollusc and crustacean). Do not depurate. • Collect sample in a suitable container. • Keep chilled at 2°C.	• Prepare softer-shelled species (such as shrimps) whole. For harder-shelled species (such as lobsters, whelks) prepare samples into two portions: 1) flesh and 2) shells. Treat as two separate samples in subsequent stages OR prepare specific portion of sample (such as the gut). • Record weights of parts required for analysis and for discarded parts (to allow for total body burden). • Oven dry sample (60°C) to constant weight. (Analyse wet for volatile radionuclides). • Record dry/wet ratio. • Homogenise sample in mill or blender. • Further prepare sample dependent upon analyses required.

Appendix B – Workshop

Workshop on Best Practice Techniques for Environmental Radiological Monitoring

Hosted by Cefas on behalf of the Environment Agency, held at Defra, Ashdown House on 8th February 2006

Note of workshop

Part A – Background and event format

1. Aim of workshop

This workshop aimed to provide Cefas and the Environment Agency with the opportunity to review and scrutinise the findings and information reported in the draft guidance and standards on best practice techniques for radiological monitoring and sampling in the environment.

In particular, the workshop provided the opportunity to incorporate the views of others and widen ownership for draft project products – in order to add value and rigour to this research contract.

The specific objectives of the workshop were to:

- **Check broadly whether participants agree with the Environment Agency's monitoring objectives.**
- **Examine whether this study had missed any examples of best practice.**
- **Explore implementation factors associated with the draft guidance (such as cost).**
- **Afford some prioritisation to the monitoring methods presented.**
- **Collaboratively discuss research needs, including any gaps identified via this study.**
- **Discuss the requirements of participants in relation to implementation of the Best Practice Guidance (such as technical barriers, cost implications of different methods).**

2. Attendance

This workshop was attended by key individuals drawn from across the United Kingdom with expertise in the field of radiological monitoring. A copy of the delegates list is attached within Annex 1.

Across the group there was some variety in terms of depth of understanding of radiological monitoring techniques. The group included both technical specialists and policy makers – this was an important strength of the event.

3. Workshop format

Workshop format comprised a morning of presentations and full group discussion focusing on a series of draft tables on radiological monitoring prepared by Cefas for the Environment Agency. Following this, the afternoon session aimed to examine specific monitoring practices across three topic areas:

- terrestrial non-foods
- terrestrial foods
- inter-tidal

Broadly, the morning was spent familiarising workshop participants with the objectives of this study and collaboratively discussing a series of strategic issues associated with the identification of best practice methods in radiological monitoring. In order to effectively run the

workshop, getting the best out of all attendees, both morning and afternoon sessions were managed using a series of previously devised structured questions. These questions were presented in tandem with a set of draft tables which were prepared as part of, and once completed, would form the core source of results for this study. A copy of the workshop agenda and the series of structured questions used to direct the event are set out for information within Annex 2. The draft tables form a sizeable document, and are available in Appendix A.

Finally, workshop participants were asked to complete an assessment form in order to evaluate the workshop. All participants were broadly happy with the event and their input to it. However, some expressed concern at the usage of the phrase 'best practice' within the title for the study. A list of the points raised by delegates on their assessment forms is supplied in Annex 3.

Part B – Key workshop findings
The remainder of this section presents a summary, in bullet form, of the principle points raised during the course of workshop discussions.

1. Warm up discussion session

An early interactive element of the workshop was the scheduling of a discussion session which aimed to build group participation via a series of structured questions linked to some draft tables on best practice options. In this session, workshop participants generally concurred with the options put forward, and the specific points raised are captured within the following sets of tables (Tables 2.1, 3.1 and 3.2) which provide a detailed breakdown of the findings of the day.

2. Table 2,1: Overview of general information captured during discussions over the course of the day.

Terrestrial food	Terrestrial non-food	Inter-tidal
Health and safety • Generic reminder • Specific for particular hazards Legality of collecting some samples? Expand preparation box – pre, post, during, and so on Study pathway/value for dose – different sampling Take out 'secondary' in the objectives. Missing and/or extras to sample types. • milk powder, dairy products • fish, crustacean • watercress • mushrooms, berries and so on Generic statement for : Bulking Drying Need to specify units or conversion factor Cereal – determine an appropriate sampling scheme. • traceability of batch • marine or harvested crop Split objectives between: Assessment of food stuff for dose Distinguish between the pathways Too much detail for preparation No edible fraction – whole sample Assessment for dose – look at raw Drinking water – Acidification or carrier addition to prevent radionuclide sorption to container walls if applicable to a particular determinand	APS + HVAS / MVAS May not be appropriate for measuring sea-to-land transfer APS cannot address all issues How efficient is the filter material? IAEA – resource of info Sample for longer than 24 hours "May pack" for I. Tritium, gases missing. 1 km is too restrictive Numbering filters Noise issues Equipment fit for purpose *Contaminated land* "Hot" – needs defining "Any" – Needs redefine objective Define performance e.g. > 10^5 Bq 20 cm Dose rate measure Units – Objective? Timescale Objective Security Levels of detection Quarter cycles? Position Integrated measurement Cheap Repeat measurements at same locations Optimal location? *Freshwater sediments* Sample depends on size of river Depth? 2°C? Perhaps < 5°C	*Objectives* Objective – frequency of sampling? – general point throughout – contain monitoring on nets, ropes – define distance from object Estuary/coastal dose rate monitoring – applies to sediments Link top 10 Environment Agency objectives and sub-definitions of individual objectives Validate models – site operators Closer collaboration between modellers and monitoring data General surveys – to identify anomalous areas Sample types – split shellfish into crustacean + mollusc Fish – commercial size Seawater: partitioning between Bql^{-1} (dissolved) and $Bqkg^{-1}$ (particulate). Need to measure/determine mgl^{-1} (suspended load) Seaweed – environmental change = fluctuating discharge *Coning and quartering* To be performed on all sub-sampling of ground samples where necessary Bulking of samples – recommended especially = for example, five fish. All biota $Bqkg^{-1}$ fresh weight Sediment Bkg^{-1} dry weight Water $Bkql^{-1}$

Terrestrial food	Terrestrial non-food	Marine
Take out H_2O_2 – too specific Give reasons for length of time to run the tap Wild foods, eggs Locally produced Identifiable source – origins are known Split objective See cereal – drying Freshwater foods missing Fruit and vegetables – take out culinary Origin/production area Inconsistency of validate dose models' in objectives Split objective Meat + meat products • split objective • take out reference to summer • freezing dependent upon radionuclide Poultry? More offal than liver (i.e.) kidney Wet is "fresh" Continuity from sampling to end results and report Milk • Origin • Preservatives dependent upon radionuclide Sampling/storage/preparation • Liquids • Solids • Radionuclides Wildlife – licensing Not frequent Three objectives Could use wildlife extras – faeces?	Why chill? Reporting dry/wet 10 < sieve size Objective dependent % < 250 µm How many samples? Sample pattern? Dry at 105°C *Grass/herbage* Sample grass 1st Fence off an area – if possible Avoid collecting soil 16 m^2 – sample all Or 5-6 kg – area depends on growth ~ > 0.5 m^2. 2°C too difficult in field *Leachate* Very difficult to achieve - 0.45 micro membrane Spot samples of time integrated estimate Road drain sediments Too specific Surface sediment OK. Appropriate tool Sample road sweepings Remove cigarette ends, crisp packets etc *Sewage/sludges* Freeze + analyse ASAP or analyse wet sample Adding H_2O_2? Smelly! Health & safety *Soil* Too prescriptive Separate root ball? In situ missing – short half-life nuclides? Stainless steel etc Sample size + number	40°C oven dried – higher temps give more difficult sample to handle We agree that freeze drying is an alternative preparation process – any reasons why freeze drying should not be used? – cost and ease *Sample and preparation* Contaminant monitoring distance + how long to count for What is performance of counter? Function tests for instruments Est. dose rate monitoring – use of TLDs General contamination – GM, Na(I), mobile detector Coastal sediments predominant sediment type to be sampled include LOI analysis (surrogate for particle size distribution) discard gravels > 2 mm analyse < 2 mm Small particles – why 4 independent NaI's? Remove fish Wet + dry total deposition Lots 1. Structure of format points Objective 1st 2. Scope + missing points Aerial survey + Scales of sampling + Minimum sample size 3. Bulking + Homogenisation Depends on objective Loss of sampling uncertainty Detection limit Risk + history 4. Sub-sampling Coning + quartering Sub-sampling for report analysis Time series Investigating unusual results 5. Reporting -Consistency 6. Health + safety Consistency Own risk assessments Too generic

3. Record of afternoon group work sessions

3.1. Responses to initial questions

Table 3.1: Responses to initial questions

Terrestrial food – initial questions
• Are you happy with the scope of guidance (i.e. preparation before sampling in laboratory, preparation in field before sampling/monitoring, sampling/monitoring and sample preparation; analysis excluded)? Need to consider/mention legal aspects of sampling (for example, wildlife work needs to be licensed). Keep generic - preparation of sampling/monitoring, weigh materials and so on. Keep objective close to the sampling process, for example avoid mismatch between the details and through the objective not matching the process. Honey example: is it sampling for pathway or monitoring for dose assessment – may be important distinction between the two (is pathway monitoring actually covered by routine?). Question over secondary in objectives - What does this mean? Remove from the objective and leave as a pathway (food may turn out to be important or unimportant). Define problem carefully, define the options, score and evaluate in a systematic approach. • Any sample/monitoring types missing? Should some be excluded as more detailed reference sources can be referred to? Milk products such as butter, cheese, powder (important pathways); freshwater fish and crustaceans amongst others are missing. Should use recent habit survey – see the FSA reports on wild foods – to understand which the types of foods should be included. • Should bulking of samples be included in scope to ensure practicability? Bulking allows you to reduce the number of analyses and it is really a decision based on economics – for example if you're expecting little activity concentration and the analysis is for long-lived radionuclides, then annual bulks are cost effective. Samples need to be fit for purpose, balance between the count time versus sample size and so on. • Should coning and quartering be included for dry granular samples other than cereal? Should use a phrase such as representative sub-sampling, dry using suitable temperature, and need to be set up, calibrated, standardised, for routine use. • Should the units and wet/dry state be defined for reporting? Yes • Should there be more guidance on health and safety? Health and safety issues – generic reminder to ensure that all practices are inherently safe or should be assessed. But particularly hazardous aspects should be highlighted. Generic link is needed between the objectives and the samplers via the analysts to ensure all are clear on what they are doing and why – there should be a joined up process that all are aware of. This point should be made in the text, where no one type of person should dictate the sampling requirement – analysts need to say how much material and in what form it should arrive, samplers need to understand the objective and analyst requirements to ensure sample is taken from appropriate location/is representative (for example, the sampling of retail versus local sites of food production) depending upon objective (national or local assessment) Storage – may want to give a separate section which describes the options and the advantages/disadvantages of the processing material.

Terrestrial non-foods – initial questions

- Are you happy with the scope of guidance (preparation before sampling in laboratory, preparation in field before sampling/monitoring, sampling/monitoring and sample preparation; analysis excluded)?

Objective is more important than sample type – especially the case with grass and soil.
Table of objectives linked to sample type needs to be presented.

- Any sample/monitoring types missing? Should some be excluded as more detailed reference sources can be referred to?

Issue of scale requires consideration.
Need to address and define 'surface water.'
Indicative minimum sample size would be beneficial.
Practical issues associated with weight and logistics of sampling.

- Should bulking of samples be included in scope to ensure practicability?

With bulking you loose matters associated with spatial variability.
Danger of overcomplicating.
Sub-core sampling?
Bulk in two ways; time or location.
Detection.
Risk history and objective.

- Should coning and quartering be included for dry granular samples other than cereal?

Rather than specify one type, better to refer to 'representative sub-sampling'. However, this may be impractical from a time perspective.
Large degree of variation potentially.
Need to assure adequate sample to repeat if necessary.
Best practice is to take a bigger bulk sample in case the need for repeat analysis arises.
Time series is essential to understand.
Investigate unusual results.

- Should the units and wet/dry state be defined for reporting?

Consistent reporting is important. Especially for the 'less experienced' user.

- Should there be more guidance on health and safety?

Aim for consistency in level of detail throughout the report.
Take care not to become a hostage to fortune. Legislation is in place and ample guidance on risk assessment.
UK has a strong regulatory framework in place.

Marine / estuarine – initial questions

- Are you happy with the scope of guidance (i.e. preparation before sampling in laboratory, preparation in field before sampling/monitoring, sampling/monitoring and sample preparation; analysis excluded)?

Frequency of monitoring
Link to Environment Agency top objectives – one or more – then sub -definitions as necessary. Check have monitoring to met all objectives.
Closer contact between modellers and monitoring data.
To spot anomalies – for contamination monitoring.
Suspended sediment in seawater – transport mechanism – split into aqueous and suspended (discussion on concentration factors in models).

Seaweed – response to environmental change – meaning response to change on discharge – use environmental indicator as the term.
Seawater or seaweed - which is better indicator? Generally seaweed, but for some nuclides seawater might be better.

- Any sample/monitoring types missing? Should some be excluded as more detailed reference sources can be referred to?

Split shellfish to crustacean and molluscs.
Benthic versus pelagic fish, size.

- Should bulking of samples be included in scope to ensure practicability?

Yes – removing variability, getting a more representative sample. Closer to the mean.

- Should coning and quartering be included for dry granular samples other than cereal?

Should be used for all ground samples, where sub-samples are required.

- Should the units and wet/dry state be defined for reporting?

Yes and happy with the units as presented. Could call wet fresh.

- Should there be more guidance on health and safety?

What happened to freeze drying? Better for volatile radionuclides.
Need to identify that freeze drying is a good method.
Volatile radionuclides have not been defined.
Forty degrees needed for sediment as harder to disaggregate if 'bake' it any higher temperature. Freeze drying better for sediment handling afterwards. Throughput slower. No comparative studies between methods.

3.2 Responses to method-specific questions applied across all three groups

The following questions were commonly applied across all three groups:

- Do you understand and are you happy with monitoring objective?
- How should sampling/preparation protocols be adopted in relation to specific radioanalytical requirements?
- Does the sampling/monitoring method as described broadly conform to your practices? If not, what are the main differences?
- Are all the key points here in each method? What is missing?
- Is the guidance too detailed or not detailed enough? What should be removed or what should be excluded?
- Are there any benefits related to the application of a particular sampling method?
- Are there any constraints on the application of a particular sampling method?
- Are there any practical issues related to the application of a particular sampling method?
- What are the implications of any change in methodology for sampling; for example, will it invalidate the previous results or make the data incompatible?
- Are the units and wet/dry state defined for reporting acceptable?

The comments made in response to these questions are set out within the table below. Responses have been grouped together for each monitoring medium. Please refer to the more detailed documents generated by each group for the full breakdown of questions/answers.

Table 3.2: Responses to method specific questions applied across all three groups

Terrestrial food	
Cereal	Harvested or mature grain in the field – it has to sample the foodstuff in the appropriate condition for use in human consumption. How to sample: there are different quantities that could have been sampled so sampling design (such as random, non-random, representative) is important; for example, if the sacks of grain area available for sampling how do you test them? Do you sub-sample out of every other one, pick one bag out of every 10 and so on? How to determine that the sampling is representative. Traceability of the product is very important, in case it turns out the batch is affected. How to capture short-lived radionuclides if the aim is dose assessment of the finished (consumable) product? Therefore, is the objective for food dose assessment appropriate for these situations? On the other hand, you have an objective for pathways/investigation (may be research orientated). Here, short-lived radionuclides might help you to understand the pathways but unlikely to be in the final product. Too much detail for generic, too little detailed for SOP, key point that came out in all aspects of food assessment was that the food should not prepared as culinary practice, it should just be the edible proportion analysed raw. Work has been done on this by HPA and over in Ireland to assess the consequences of food preparation and it is easier to quantify if the foods are not prepared. Prepare raw foods to avoid losses of materials. Some culinary preparation may lead to concentration or losses – 50 to 80 per cent, for example depending on use of liquor or not from cooking. Often this culinary preparation can be used to reduce food consumption rates (as advice) under circumstances where It is applied as a countermeasure to reduce the activity concentration in a given food product. Therefore, the dose assessment would be conservative by analysing raw.
Tap water	Omission when describing sample water from tap – needs the addition to the bottle of a carrier and acidification if needed and as appropriate for the radionuclide(s) of interest suggest tabulate the radionuclides that required a carrier. Radon – the sampling would be more important and likely to require separate protocol. Do we need to consider naturals? Generally felt should be generic – and therefore not specific to the technique. Too far with the particles in the preparation describing the use of H_2O_2. What are you trying to do when running the tap for 10s? Why is this? Maybe longer? Do we want mains water or what is in the tap?
Eggs, game, honey	Wild foods should be considered and not just retail, depending upon the purpose. If you want to know the dose to the local population from a nuclear site need to focus on locally identified, source of production (origins are known) foodstuffs to identify the impact of local site. But for the population/national, then you may choose a supermarket/retail approach. Needs to cover both options. Culinary as above in cereal Specify units – fresh/dry matter basis. Standards should be appropriate to the material being sample. Eggs should be removed and kept as a separate item. Other wild foods should be included (see list to be generated from the wild food reports for FSA).
Freshwater (surface)	Relevance not understood here – is this freshwater consumption or should it be freshwater fish/crustaceans and so on? Need to clarify objective/sampling type. Points made under other sections would be relevant here.
Fruit/ vegetables	Culinary issues as noted previously. Drying too specific? Need to know the wet/dry conversion. Production area needs to be known again for traceability. Dose model validation as an objective – the point was made that monitoring approach data has never been very successfully used to validate models in the experience of the group. Furthermore, dose model validation work would need to be broader and include soil and other media for food transfer of radionuclides and the dosimetry, but it is inconsistent in its application at the moment throughout the tables.
Freshwater (ground)	Similar to drinking water? Where sampling? Using boreholes or at the site where groundwater resurfaces i.e. springs? Need to clarify purpose and sampling point/economics of sampling using boreholes etc. Is this very different from tap water source in terms of dose monitoring except for a critical group drawing water locally and direct from groundwater? Appropriateness of objective?
Meat/meat products	Sample type is actually meat not the meat products (should it be?). Describe as meat and poultry; i.e., all farmed meat. For clarity? Samples in summer – note cattle? Dairy in the fields in summer – is this not highly specific? Should the meat/product not be sampled at any time when it is ready and not constrained to the summer? Separate the species?

	Culinary preparation as previously. Kidney may want to be considered; liver, muscle already mentioned. The three types of meat products should be considered. Drying temperature too specific Basic for all – the list of radionuclides for volatiles Not wet weight but fresh weight.
Milk	Dairies not the farms– so locally produced? Preservatives – may be required and this would be related to the radionuclides Do not let milk rot before freezing?
Wildlife	Wildlife – specific mention of culling may not be appropriate within such a document – should the Environment Agency advocate culling for wildlife assessments or highlight the need for ad hoc sampling based on road kill? Need for licences? From wildlife and countryside act list species; that is, cover legal aspects – sources of further information Two objectives: one for assessing exposure to wildlife (hence links to validation of models); other on the transfer of radioactivity off-site (is this routine monitoring?). Distribution off-site – then you might sample faeces etc? Indirect methods. Transfer and spread, not just identify species present, where are they in the environment? Faeces? Skin feathers – entrails – may need to identify why you are measuring the material and whether there are particular purposes for doing things, for example low level betas, and consequences of sub-sampling of the organisms from whole bodies?
Additional notes	As detailed as it is at the moment. Sample design – where, when and how you go. There needs to be more on the broader picture. Review of the fitness of purpose for the design side to check that it continues to or meets the objectives. Common practice versus specific advice for particular areas. Project officer to discuss with the EC organisations to review the concepts of best practice against the document.

Terrestrial non-food	
Air passive shades (APS) and High/Medium Volume Air Sampling (HVAS / MVAS)	Sea/land transfer may not be appropriate? Don't think APS can address objective. How efficient do you want your filter to be? What fraction of dust particles do you wish to collect? Flow meter is important. Sample for 24 hours is too specific. Some sample for two weeks. Tritium is missing – + gases generally. One km too restrictive. Try to stick with general guidance and not get too into the method. Some are happy for Environment Agency to set procedures (AWE/Sellafield). Noise and expense are additional issues.
Contaminated land	Units keep changing, therefore comparability between time is quite difficult. Timescale - Depends on what you are trying to measure. Also relates to security of sample programme. Quarterly? Position at chest height on a fence. Take care to not stifle innovation by being too prescriptive with regard to instruments used. Determine number of counts required from instrument, rather than time period. Need consistency in terms of monitoring location. Optimal location is away from trees, but in reality may not get a choice.
Dose rate monitoring	Units keep changing, therefore comparability between time is quite difficult. Timescale - Depends on what you are trying to measure. Also relates to security of sample programme. Quarterly? Position at chest height on a fence. Take care to not stifle innovation by being too prescriptive with regard to instruments used. Determine number of counts required from instrument, rather than time period. Need consistency in terms of monitoring location. Optimal location is away from trees, but in reality may not get a choice.
Freshwater sediments	Depends on size of river and flow. 50 cm seems too deep. How do you identify sediment type out in the field? Why 2^{o}C? How do you chill in the field? Why are we chilling them? 10 cm core – large diameter, less smearing. Need to mention practicality of freeze drying. Problem when guidance gets too specific. Large stone removal? Sieving or crushing. Be specific about what you are analysing and not. Report dry to wet ratio, and what percentage of material failed to pass particular sieve size.

	[Define limitations and assumptions taken]. Change from 500 microns to 250?
Grass/Herbage	Method seems a bit complicated. Good to have set location to return to. Collect vegetation sample, before soil. Fence sample area if you can. However, not possible to control in a public access area. Is area applicable? 4 x 4 area 16 m^2 Grab sample by weight. (5-6 kg?) But have to measure the area. What do you collect (ideally) grass, meadow, rough stuff? Dry at 105^{o}C. But take care for volatiles. Freeze.
Leachate (landfill)	Weigh membrane to see how much solid collected. Take care in practical terms. Horses for courses, decide what you really want? Scientific sense to separate dissolved from particulate. However, this may have practical/cost constraints. Analyse both fractions. Or have a combined sample. Spot samples or time proportional bulk. Purge borehole first.
Road drain sediments (gully pots)	Collect what you can. Too specific Appropriate tool. Consider depth of gully pot. Alternative if you have control over road sweeping is to sample that as well. Remove rubbish. (such as litter, cigarette ends). Clean out after sampling so you can't resample. Know when drain was last cleaned?
Sewage sludges	Freeze and then ash, or analyse wet sample. Can be too liquid, to dry. Query use of peroxide.
Soil	Don't need 'short-lived' Worried about specifying set methods like this. Cut grass off top, and analyse root and everything below. Practical. Wouldn't go as deep as 50 cm. Look at surface and see if anything is underlying. Remove roots, but really impractical in a turf and most cases. Depends on how dry soil is. Have experimented by digging trial pits (Sellafield). Some just take a turf, due to time constraints. Others take three samples. Galvanised steel not stainless. In situ gamma spectrometry.
Wet, dry, total deposition	Collect in a rain gauge. Keep track of rainfall and calculate likely volume. Use a carrier solution. Background to be taking for monitoring Cal time is very prescriptive. Calibrations for field work are easy to say, hard to do.

Inter-tidal	
Contamination monitoring	Specific to ropes, nets, pots. How close to net, how much net thickness. How long do you count for? Can integrate over time Function test before and after Specify detection capability, rather than an instrument. Sensitivity/efficiency calibration.
Estuarine/ coastal dose rate monitoring	To sediments Should TLDs be included? Refer to *Technical guidance note (Monitoring) M5* report Should be three locations. Function checks If taking out instrument need to take out count time.
Estuary/coastal contamination monitoring - general contamination	How above is just above the surface? You could use a NaI detector – this would be more akin to best practice.
Estuary/coastal sediments	Didn't like two degrees for chilling. Collect sands and muds, therefore discarding gravel. Sieving to remove larger stones. What doesn't go though 2 mm does not get analysed. Grain size considerations. Loss on ignition at 450 degrees good proxy for grain size. Go for predominant sediment type at location. Cores can be more than 50 cm. Compression problem going deep, top more compressed. Recommendation on core diameter.
Estuary/coastal contamination monitoring – small particles	Question on the four independent detectors What about depth of particles would you see them?
Fish	Human exposure. Juveniles might be bottom-feeding, but become pelagic as older.
Seawater	Dissolved and particulate phases. Can filter to 0.45 micron.
Seaweed	No notes.
Shellfish	No notes.

Delegates list

Beth Greenaway	Defra, MWD
Nick Wood	Food Standards Agency
Ian Robertson	SEPA
Ciara McMahon	RPII, Ireland
George Ham	Health Protection Agency
Bernie Wilkins	Health Protection Agency RPD
Lorna Mitchell	Health Protection Agency Glasgow
Sonja Shaw	Harwell Scientifics
Adrian Clacher	AmecNNC - NIRAS
Paul McDonald	Westlakes Scientific Consulting
Nick Beresford	CEH
Julian Dean	NPL
Gary Bird	LGC
Callum MacNeil	Isle of Man Government Lab
David Jones	BGS
David Sanderson	SUERC
Steve Mudge	Bangor University
Jim Desmond	BNGSL
Richard Greenwood	AWE
Matthew Emptage	Environment Agency
Geraldine Guiget-Doran	Harwell Scientifics
Andrew Tyler	University of Stirling
Stephanie Long	RPII, Ireland
Kins Leonard	Cefas
Kathy Kennedy	Cefas
Stephanie Cogan	Cefas
David Copplestone	Environment Agency
Rob Allott	Environment Agency
Jane Rowe	Environment Agency
Tony Ganner	Environment Agency

Workshop agenda and list of structured questions

10.00 **Arrival and coffee**

10.15 **Welcome and introductions**

10.25 **Presentations**

- Introduction to workshop objectives and methods to be adopted [5 mins]
  Kathy Kennedy (Workshop facilitator)
- Environment Agency Policy on Radiological Monitoring [10 mins]
  Rob Allott (Technical Manager Monitoring and Assessment, Environment Agency)
- Best Practice Techniques for Environmental Radiological Monitoring: Project progress and key issues for discussion [15 mins]
  Dr Kins Leonard (Radiological Protection Topic Leader, Cefas)
- Questions and answers [5 mins].

11.00 **Discussion session**
Facilitator to lead group discussion aimed at warming people up and eliciting key general items of information on Best Practice in Radiological Monitoring, using structured questions and a PowerPoint of draft tables.

12.00 **Lunch**

12.45 **Group work**
Three parallel groups, each with a facilitator. Focusing on scrutinising of elements of draft report tables and discussing associated implementation challenges. Groups to be split thematically:

A. Terrestrial (non-foods) - Dr Rob Allott
B. Terrestrial (foods) - Dr David Copplestone
C. Marine - Dr Kins Leonard

14.15 Feedback session – results of group work [10 mins per group]

14.45 Discussion / conclusions session

15.55 Thanks and goodbye.

General questions

- How do you view the quality/general standard of environmental radiological monitoring within England and Wales at the moment? Is there room for improvement? Where specifically?
- What in your opinion are the main barriers to consistent best practice in radiological monitoring across England and Wales? (for example, cost, lack of data, continuity problems)
- How were your own monitoring/sampling procedures developed? Standards, guidance, experience?
- Do you feel there any specific monitoring media where there are gaps in monitoring/sampling procedures? What do we need to do to fill these gaps?

Questions for best practice options (Table 4) – Asked about the options for each monitoring type

- Are you aware of any other means of radiological monitoring for this monitoring type which would achieve the objective?
- Are there any other strengths and weaknesses that should be recorded?
- Do you have a preferred technique and for what reasons?

Questions for sampling methods (Table 3) – Initial questions

- Are you happy with the scope of guidance (preparation before sampling in laboratory, preparation in field before sampling/monitoring, sampling/monitoring and sample preparation; analysis excluded)?
- Any sample/monitoring types missing? Should some be excluded as more detailed reference sources can be referred to?
- Should bulking of samples be included in scope to ensure practicability?
- Should coning and quartering be included for dry granular samples other than cereal?
- Should the units and wet/dry state be defined for reporting?
- Should there be more guidance on health and safety?

Questions for sampling methods (Table 3) – Asked about each monitoring type

- Do you understand and are you happy with monitoring objective?
- Does the sampling/monitoring method as described broadly conform to your practices? If not, what are the main differences?
- Are all the key points here in each method? What is missing?
- Is the guidance too detailed or not detailed enough? What should be removed or what should be excluded?
- Are there any benefits related to the application of a particular sampling method?
- Are there any constraints on the application of a particular sampling method?
- Are there any practical issues related to the application of a particular sampling method?
- What are the implications of any change in methodology for sampling; for example, will it invalidate the previous results or make the data incompatible?
- Are the units and wet/dry state defined for reporting acceptable?

Questions for wash-up

- Would your organisation be willing to change or to consider changing their sampling methods on the basis of any best practice identified within the report to be produced?
- Should any changes be identified as being needed, should they be done all at once, over time or should both the existing and new sampling method be run in parallel for a time? What are the implications of the change (financial, staff, equipment issues, public views and so on)?
- What level of detail should be included in the final guidance, what should be included or left out, what would be useful?

Summary of additional reference material/comments supplied within workshop assessment forms

Dave Jones, BGS	2004 IAEA Guidance on Gamma Spectrometry.
Ciara McMahon, RPII	US MARSSIM and/or MARLAP manuals.
Richard Greenwood, AWE Aldermaston	Current practice by UK operators (Questionnaire). USEPA for contaminated land, data quality objectives (see website). Blue book methods? An ongoing working group would be valuable (➔EA for info).
Andrew Tyler (University of Stirling)	References supplied to Rob Allott
Nick Wood (FSA)	Crustacean; work on numbers of animals needed to adequately reflect r/n concentrations in populations by Dave Swift and Mike Nicholson for MAFF.
Jim Desmond, BNGSL	Possible source of outline sampling is the various CEAR documents.
Steve Mudge (University of Bangor)	The 'sample design' aspect is lacking so how do you link objectives to method? Balance on prescription of methods needs to be there – not too vague and not 'you must use this instrument'.
Callum MacNeil, Govt. Lab. Isle of Man	Potential problems of pseudo-replication of samples needs to be addressed.
Tony Ganner, Environment Agency	Nuclear industry's 'Safegrounds' work on contaminated land, identifying best practice. Work on data quality objectives (DQOs) – see DQO on Google search.

We welcome views from our users, stakeholders and the public, including comments about the content and presentation of this report. If you are happy with our service, please tell us about it. It helps us to identify good practice and rewards our staff. If you are unhappy with our service, please let us know how we can improve it.

We are The Environment Agency. It's our job to look after your environment and make it **a better place** – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

Published by:

Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk