**Radiological Monitoring Technical Guidance Note 2**

# Environmental Radiological Monitoring

**December 2010**
**Version 1.0**

## Contents



**About this technical guidance note**

This guidance note has been published jointly by the Environment Agency, Scottish Environment Protection Agency and the Food Standards Agency. It has been developed by the Radiological Monitoring Standards Working Group (RMSWG). The RMSWG has representatives from the Environment Agency, Scottish Environment Protection Agency, Nuclear Decommissioning Authority, Food Standards Agency, nuclear industry and experts. The RMSWG is a sub-group of the Nuclear Industry Liaison Group.

# 1 Introduction

1.1 Environmental radiological monitoring is undertaken by operators to comply with their authorisations under the Environmental Permitting Regulations 2010 (EPR 2010) [Ref 1] or Radioactive Substances Act 1993 (RSA 93) [Ref 2]. This monitoring is also carried out by regulatory bodies (Environment Agency, Scottish Environment Protection Agency, Northern Ireland Environment Agency, Food Standards Agency) in support of their regulatory roles under EPR 2010 or RSA 93 and other national and international obligations.

1.2 This document provides guidance on planning and implementing routine environmental radiological monitoring programmes. Guidance is provided on the objectives and principles underpinning monitoring programmes, for both operators and regulators, providing clarity on the monitoring roles. The process for defining monitoring programmes, including stakeholder engagement, where appropriate, is also presented.

1.3 The guidance considers programme design, giving guidance on what to monitor, where and how often. Further guidance is provided on the monitoring and sampling techniques to be employed.

# 2 Scope

2.1 This document provides good practice guidance on how to design environmental radiological monitoring programmes. This guidance is aimed primarily at designing new or reviewing existing environmental radiological monitoring programmes around nuclear licensed sites for the purpose of monitoring the environmental effects of authorised discharges. Monitoring for short term releases would follow similar practices, but with increased frequency of monitoring and numbers of locations. It also applies to programmes designed to meet international obligations. The guidance may be applied to environmental monitoring programmes around non-nuclear sites, if this monitoring is required. It will help nuclear operators comply with the requirements to use Best Practicable Means or Best Available Techniques when designing and implementing their environmental radiological monitoring programmes. The Food Standards Agency's own food monitoring programmes in England and Wales are currently under review and this guidance may be amended in the light of the outcome of this evaluation.

2.2 Although incident and effluent monitoring are outside the scope of this guidance, a routine monitoring programme should have elements designed to indicate if there has been an accidental or unauthorised release. Follow up characterisation of any such unauthorised release or incident would then be undertaken as a separate investigation. The sampling and monitoring techniques to be employed may be based on those presented in this guidance.

2.3 Scientific investigations into the behaviour of radionuclides in the environment are outside the scope of this guidance, except for routine monitoring to identify significant changes in the environment (e.g. in dynamic estuaries). The data from routine radiological monitoring programmes may be used to supplement these scientific studies.

2.4 Baseline radiological monitoring prior to the development of a new nuclear site or new discharge is outside the scope of this guidance as this will usually be defined as an investigation project. However, as with scientific investigations, data from routine monitoring programmes may supplement baseline studies, as long as any constraints on the data are understood.

# 3 Environmental monitoring objectives

3.1 For any monitoring programme it is important that there are clear objectives to be achieved. Generic objectives for environmental radiological monitoring programmes are:

- Objective A - Assess total representative person (see definitions) dose.
- Objective B - Assess dose as an operator's performance measure.

- Objective C - Assess total impact on wildlife (e.g. dose). [Ref 3]
- Objective D - Assess impact on wildlife as an operator's performance measure (e.g. dose).
- Objective E - Provide public and stakeholder reassurance.
- Objective F - Check / complementary monitoring.
- Objective G - Assess background (very far field).
- Objective H - Assess long term trends (Indicator).
- Objective I - Comply with international obligations.
- Objective J - Detect abnormal, fugitive and unauthorised releases (Indicator).
- Objective K - Understand / monitor behaviour of radio-nuclides in the environment.

3.2 Further definitions of these generic objectives are provided in Table 1. The table indicates where the responsibility lies for monitoring to meet a specific objective and gives some guidance and criteria for when it would be necessary and what should be considered in the monitoring.

3.3 These objectives apply to routine environmental radiological monitoring programmes. Some programmes may be undertaken to achieve other objectives, for example:

- Workforce reassurance.
- Baseline environmental monitoring for a new source or discharge.
- Scientific investigations.
- Incident investigations.

# 4 Environmental monitoring principles

4.1 Environmental radiological monitoring programmes should be designed to meet the following generic principles (not necessarily in order of merit):

- ***Principle 1 Health and Safety*** – The benefits of the programme should be balanced against health and safety requirements and elements with a potentially elevated risk only proceeded with if the risk can be reduced to an acceptable level.
- ***Principle 2 Benefits exceed impacts*** – The benefits of the programme should exceed any significant environmental detriment (i.e. be environmentally sustainable).
- ***Principle 3 Satisfy international requirements*** – Programmes should satisfy or be compatible with international requirements or guidance where available (e.g. IAEA Safety Standard on environmental and source monitoring [Ref 4], Article 35 of the Euratom Treaty).
- ***Principle 4 Objective based*** – Programmes should be based on defined objectives and monitoring of different exposure pathways clearly linked to at least one objective.
- ***Principle 5 Proportionate*** – The design and management of programmes should be proportionate to past, current and future potential impact of discharges on humans and wildlife. Other considerations in determining the proportionality of the programme will be the cost, the environmental impact of undertaking the programme, the type of environment (including how dynamic it is), the likely behaviour of radionuclides in that environment (including half-life) and current state of knowledge. It will generally be proportionate to have a larger environmental monitoring programme where the dose from discharges to air or water exceed 0.02 mSv $y^{-1}$ to ensure that a realistic dose assessment can be performed [Ref 5]. It will not be generally proportionate to require monitoring where the dose from a particular pathway is <0.001 mSv $y^{-1}$, unless monitoring is required to satisfy objectives related to assessing background and long term trends, complying with international obligations, detecting abnormal, fugitive and unauthorised releases, understanding behaviour of radionuclides in the environment or be useful for check monitoring (objectives F, G, H, I, J and K).
- ***Principle 6 Complementary*** – The regulators should ensure that their programmes and those of the operator address all the appropriate monitoring objectives whilst avoiding unnecessary duplication.

- ***Principle 7 Satisfy stakeholder concerns*** – Programmes should consider legitimate stakeholder concerns and expectations, as far as reasonably practicable.
- ***Principle 8 Based on authorisations*** – Specific radionuclides should be selected for the monitoring programme, based on the source term (taking into account the magnitude of release and environmental impact) and radionuclides limited by EPR 2010 / RSA 93 permits/authorisations, including those that could be released as fugitive emissions.
- ***Principle 9 Optimised*** – Programmes should be optimised to achieve the maximum number of objectives from a minimum number of samples, ensuring that sufficient monitoring data of an acceptable quality are collected for all the objectives to be achieved.
- ***Principle 10 Meet quality standards*** – Programmes should be undertaken to defined quality standards equivalent to ISO9001, ISO 14001 and ISO17025 [Refs 6-8].
- ***Principle 11 Appropriate performance criteria*** – Performance criteria for the monitoring programme (in particular uncertainty criteria, limit of detection, analysis turnaround) should be designed to allow the objectives to be met, whilst ensuring proportionality (see Principle 5). Different objectives will have different performance criteria (e.g. for detecting abnormal releases a relatively quick analytical turnaround will be important, but a higher detection limit may be acceptable).

# 5 Process for designing environmental monitoring programmes

5.1 Figure 1 outlines the process which should be used by regulators and operators for designing, implementing and reviewing environmental monitoring programmes. Operators should seek agreement of the monitoring objectives for their programmes from the relevant regulator and will need to formalise the monitoring arrangements with the regulator prior to implementation. More guidance is provided in the next section on how to design the monitoring programmes.

5.2 This process may be used for designing new or reviewing existing monitoring programmes. Clearly there will be more information available for existing monitoring programmes.

5.3 Once the programmes have been implemented there will need to be review processes in place to ensure they remain fit for purpose. More guidance is provided in section 6.8.

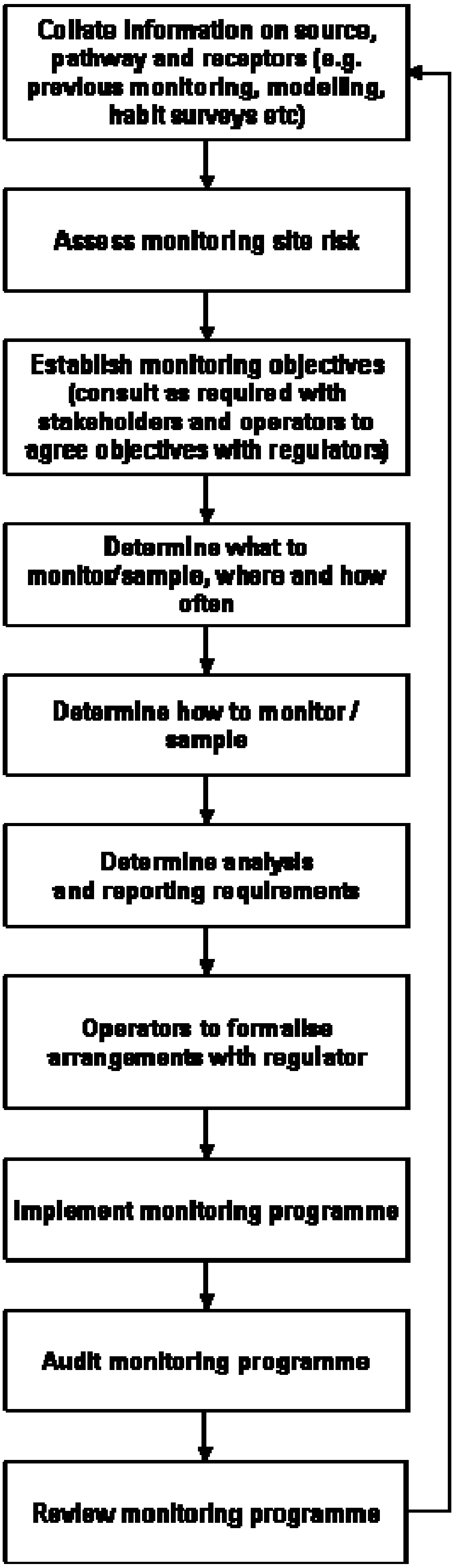


**Figure 1 Process for designing, implementing and reviewing environmental radiological monitoring programmes**

# 6 Design of environmental monitoring programmes

## 6.1 General

6.1.1 The International Atomic Energy Agency (IAEA) has published a safety standard on environmental and source monitoring [Ref 4]. It provides information for sampling and monitoring types, primarily aimed at terrestrial and freshwater environments, with suggested sampling frequencies. This standard provides only limited guidance on the number of locations which should be monitored around a nuclear site. Appendix 1 provides an interpretation of the IAEA Safety Standard with low, medium and high numbers of monitoring locations to help define a range of sample numbers per year. This interpretation has been used to provide a framework for the guidance in this document on what should be monitored, where and how often.

6.1.2 The United States Environmental Protection Agency has developed a systematic planning approach using the Data Quality Objectives Process (DQO) which provides information on how to apply systematic planning to generate performance and acceptance criteria for collecting environmental data to sufficient quantity and quality to support the goals of a study [Ref 9]. A series of logical steps are used that apply to both decision making (e.g. compliance/non compliance with a standard) and estimation (e.g. ascertaining the mean concentration level of a contaminant). The Data Quality Objectives process was not developed specifically for routine environmental monitoring programmes and the Environment Agencies and Food Standards Agency are developing their position on how it may be used for this purpose. It may have the potential to support detailed consideration of particular aspects of a monitoring programme (e.g. frequency of soil sampling). However, undertaking a full DQO assessment for every sample type/objective combination for a routine monitoring programme is likely to be resource intensive.

## 6.2 Collate information

6.2.1 When designing a new monitoring programme it will be necessary to develop a conceptual model of the source, pathway and receptors which will include consideration of the following:

- The type of facility and the stage of its life-cycle (e.g. commissioning, operational, decommissioning).
- Information about the environment around the site. This could include the land use types (including details on agriculture), water body types, water flow rates, freshwater and seawater boundaries in estuaries, sites of accretion and erosion in rivers and estuaries.
- Information from existing monitoring programmes or from monitoring programmes at similar sites. In particular, this might identify likely areas where radionuclides might accumulate.
- Information from habit surveys (existing and/or new). Guidance for undertaking habit surveys is provided by the National Dose Assessment Working Group (NDAWG) [Ref 10]. These will identify what sorts of food are being consumed and from where and also where people spend their time. This will be valuable information for designing monitoring programmes to meet the dose based objectives (Objectives A and B).
- Modelling and existing monitoring data to predict the behaviour of radionuclides in the environment around a site, taking into account meteorological conditions (such as wind speed and direction), tidal currents etc. This will help target the areas of highest activity concentration or likely activity concentrations in places which might lead to exposure of people or wildlife.
- Trial monitoring (e.g. using instruments) to investigate the areas of highest activity concentration or likely activity concentrations in places which might lead to exposure of people or wildlife.
- Suitability of monitoring locations to meet the required objectives. For example where the dose impact of current discharges is being assessed by monitoring estuarine sediments, an area of accreting sediment will need to be monitored.
- Investigate the likely spatial and temporal variability in activity concentrations at monitoring locations to ensure that it is acceptable for the purpose of the objective, using monitoring

trials or the judgement of suitably qualified and experienced persons. This will be important if the exact location for sampling could vary (e.g. due to access difficulties).

6.2.2 When reviewing an existing radiological monitoring programme it will be necessary to consider the same factors as those for the new programmes, together with the following:

- Stakeholder expectations about monitoring for reassurance purposes.
- Impact on long-term trend data.
- Knowledge of optimal sample/monitoring types (e.g. dose rate rather than soil analysis).

## 6.3 Assess site impact

6.3.1 A useful first step in designing a monitoring programme is to establish the level of impact associated with the site and the presence of sensitive receptors. The term impact is used in a wide sense to include both environmental impacts (from discharges and potential from abnormal releases) and business risks (e.g. reputational risks). The magnitude of effort in designing and carrying out the monitoring programme should be commensurate with this level of impact. The levels of impact are defined as follows:

- ***Programmes for lower impact sites*** – The discharges are reasonably uniform with a low potential for abnormal releases, the environment is well characterised, the dose to the representative person (assessed from initial monitoring results or modelled at discharge limits) is less than 0.02 mSv $y^{-1}$ for all exposure pathways; and there is low public concern.

- ***Programmes for higher inpact sites*** – There is the potential for abnormal releases; the environment is complex and difficult to characterise; the dose to the representative person (assessed as above) is greater than 0.02 mSv $y^{-1}$; or there is high public concern.

6.3.2 Hence, in general, where the impact is low, the monitoring programme would be expected to be relatively small. The minimum programme for a lower impact site is only likely to need to address the objectives of providing pubic and stakeholder reassurance, and detecting abnormal, fugitive and unauthorised releases. Also the quality assurance requirements can be less stringent. A quality management system would still be required striving to meet the principles of the relevant ISO standards, but not necessarily accredited. Assessing the impact helps ensure compliance with Principle 5 on proportionality.

6.3.3 For sites with the lowest impact (e.g. dose from discharges to air or water are less than 0.001 mSv $y^{-1}$, no legitimate public concern and no potential for abnormal releases) there may be no requirement to address even the minimum objectives of providing pubic and stakeholder reassurance, and detecting abnormal, fugitive and unauthorised release, and hence no programme will be required.

6.3.4 As site operations change and move through decommissioning and into care and maintenance the levels of impact associated with them will change and this should be taken in to account when reviewing the programme (see section 6.8).

## 6.4 Establish monitoring objectives

6.4.1 The relevant monitoring objectives should be established, when designing a routine radiological monitoring programme (see Section 3 and Table 1). This satisfies Principle 4 on objectives. The monitoring objectives which are selected will reflect who is undertaking the programme, its scope and the site impact. Hence an operator will not be concerned with the objectives relating to the total representative person dose (Objective A) or very far field backgrounds (Objective G). A regulator's programme for monitoring around all nuclear sites may require most of the monitoring objectives to be achieved, whereas an operators programme for a single nuclear site will have a smaller number of objectives. It is unlikely that the objectives relating to dose and impact on wildlife (Objectives A, B, C and D) will be relevant for a low impact site programme.

6.4.2 The sample or monitoring types which may be used to help achieve each objective are shown in Table 2.

6.4.3 Operators should ensure that the regulators are satisfied with the selected monitoring objectives. For all monitoring programmes, it may be appropriate to consult with local stakeholders over the selected monitoring objectives.

## 6.5 Determine what to monitor, where and how often

6.5.1 Guidance on what to monitor or sample, where and how often, to meet different monitoring objectives is provided in Table 3. Hence, this guidance can be used to select the monitoring and sampling types which meet the programme objectives and the sampling or monitoring approach (e.g. location and frequency of monitoring) can then be determined. Not all the sample/monitoring types in Table 3 will apply to every situation, for example sites with High Volume Air Samplers (HVAS) may not deploy passive shades and vice versa for atmospheric particulate sampling.

6.5.2 Where the behaviour of radionuclides can be affected by changing environmental conditions such as meteorology, consideration should also be given to collecting supplementary data e.g. wind direction and wind speed. This could be used to optimise the position of monitoring points and the data could also be used to confirm the source of any unusual or elevated measurements.

6.5.3 The total number of samples or monitoring activities (monitoring locations at different times) around a nuclear site or in a national programme should fall within the range of total samples/monitoring activities per year indicated in Table 3 for either the regulator or operator. It is expected that the total number of samples or monitoring activities will lie in the bottom half of the range for programmes for lower impact sites and in the top half for programmes for higher impact sites. A larger number of samples would be required if doses approach the dose constraint.

6.5.4 Where a sampling or monitoring type is being undertaken to fulfil a number of objectives (which is the recommended approach and will often be the case) the total number of samples or monitoring activities should take account of the fact that some samples or monitoring activities will address more than one objective. Hence, double-counting of samples or monitoring activities should be avoided when calculating the total number of samples or monitoring activities.

6.5.5 Often the monitoring for one objective will satisfy the monitoring requirements for a number of other objectives, for example monitoring to assess total representative person dose (Objective A) could also embody monitoring to provide public and stakeholder reassurance (Objective E). The exceptions are where sampling or monitoring is carried out to assess the background, impacts on wildlife (in some cases) and for detecting abnormal or fugitive releases. Where there are national programmes designed to assess the background or comply with international requirements, additional site specific background sampling requirements may not be required.

6.5.6 Table 3 indicates which programme is meeting an objective – i.e. regulator or operator through the use of prefixes R and O. Where different samples/monitoring would be required to meet different objectives e.g. for the regulator programme, assess total representative person dose (Objective A) and assess background (Objective G) the components of the programme are indicated as R1 and R2. Where the same samples/monitoring or a subset of these can be used to fulfil other objectives this is indicated by putting the objective code in brackets. For example for 3.4 in Table 3 "provide public and stakeholder reassurance" (Objective E) could be a sub-set of the "assess total representative person dose" hence for 3.4 of Table 3 against Objective E this is indicated as (R1). This does not indicate priority between the objectives, but is based on the objective for which the greatest number of samples is required.

6.5.7 Where regulators and operators take similar samples to fulfil slightly different objectives (e.g. for the regulator to assess total representative person dose, Objective A, and the operator to assess dose as a performance measure, Objective B, these samples or monitoring activities may also fulfil the check/complementary monitoring objective (Objective F). Also, for programmes for lower impact sites, it may be appropriate for the regulator to carry out monitoring to achieve a particular objective, rather than the operator. For the assessment of background (very far field) (Objective G) if there is a national programme being undertaken there may be no need to take additional background samples for a particular site.

6.5.8 When deciding upon the frequency or timing of sampling, the following should be considered:

- Some objectives will require higher frequencies (e.g. detecting abnormal releases) whilst lower frequencies will be acceptable for other objectives, for example check monitoring (Objective F) or far field backgrounds (Objective G).
- Frequencies may be lower where the discharge profile is relatively stable (i.e. quantities discharged are relatively similar on a month by month or quarter by quarter basis). Monitoring may be timed to occur after a release if it occurs very infrequently.
- Higher frequencies may be necessary where short-lived radionuclides are being monitored.
- Frequencies should be consistent with the rate of change observed in the environment (i.e. lower rates of change will lead to lower frequencies).
- Frequencies should be higher where action levels (e.g. dose constraint) are approached.
- Monitoring may be timed to coincide with particular food growing seasons or activities of members of the public (e.g. beach occupancy).
- If short term measurement campaigns are being undertaken, for example for measurement of air particulate using HVAS, seasonal factors such as wind direction should be taken into consideration.

6.5.9 The final monitoring programme design should satisfy all the monitoring principles.

## 6.6 Determine how to monitor and sample

6.6.1 Guidance on how to monitor different sample types to achieve particular objectives is provided in Table 4. It has been updated from Environment Agency's best practice techniques for environmental radiological monitoring [Ref 11].

6.6.2 For each sample or monitoring type, there are general considerations to be taken into account, along with guidance on the actual sampling / monitoring technique and subsequent initial sample preparation. For a particular sample or monitoring type, the process carried out may need to be different to meet different objectives – hence the tables in Table 4 present the guidance grouped by the objectives which can be met by that sampling or monitoring technique. For example, undertaking sediment sampling for detecting abnormal releases requires surface scrape samples to be taken, but core samples would be more appropriate for understanding the behaviour of radionuclides in the environment.

## 6.7 Determine analysis requirements

6.7.1 For current discharges, analysis should be considered for those radionuclides which are limited in discharge permits or are significant components of a group limit (e.g. strontium-90 limited under any other beta/gamma emitting radionuclide group limit). This satisfies monitoring principle 8 on programmes being based on authorisations. Other radionuclides may be required as a result of international obligations or backgrounds. Proven surrogate radionuclides may be used (e.g. where the radionuclide fingerprint is relatively stable).

6.7.2 For historical discharges, and potential abnormal releases account needs to be taken of what radionuclides have been or could be expected to be released. As for current discharges, the programme can be optimised to those radionuclides giving the highest dose or known to accumulate in the environment and proven surrogates could be used.

6.7.3 For both current and historical discharges, in-growth of daughters may need to be considered (e.g. americium-241 from plutonium-241).

6.7.4 Results need to be appropriate for the monitoring objective for which they are gathered, for example limits of detection need to be stringent enough to allow useful data to be generated, but not too onerous as to incur excessive cost. As a guide, limits of detection should be no higher than the activity concentration which could give rise to a dose of 0.0003 mSv $y^{-1}$ for the dose related objectives (Objectives A and B) and public reassurance objective (Objective E) or no higher than 10% of the peak concentration for the indicator objectives (Objectives H, J). Different analytical methods can be used, again taking into account the use to which the data will be put and whether a screening value is good enough or accurate information is required.

6.7.5 Clearly, samples containing radionuclides with short radioactive half-lives need to be analysed quickly. The speed with which an analysis can be undertaken will also be important where there is a need to have an early warning of abnormal or fugitive release. In this case, there will be a balance between the speed of the analysis to satisfy the early warning requirement and ensuring that the results are of sufficient quality, particularly as there may only be a few results.

6.7.6 Only a limited set of radionuclides need be analysed for samples collected to meet the assessment of long-term trends objective (Objective H).

## 6.8 Review monitoring programme

6.8.1 Both operator and regulator programmes should be subject to review on a periodic basis, this would typically be an annual high level review, with a more thorough review within a 3-5 year timeframe. The frequency of this will be dependent on the variability of discharges and environmental concentration and the availability of new information (e.g. habit surveys, changes on site (operational to decommissioning), changes in farming practices etc).

6.8.2 Audits of monitoring programmes may also be undertaken by operators and regulators and the findings of these audits should also feed in to the review process.

6.8.3 It may be appropriate for the review to involve local communities and to ensure they are aware of the results of the programme and have the opportunity to raise issues.

6.8.4 The review should consider whether the objectives for the monitoring programme are still valid. If other objectives are identified, these may already be achievable through the current programme, if not, further monitoring would be required. If objectives are no longer required care needs to be given to removing monitoring to ensure that samples are not being removed that are still required to meet other objectives.

6.8.5 If over time the results are consistent and at, or close to, the limit of detection and there is a decreasing discharge profile the frequency of monitoring could be reduced. The number of locations (spatial distribution) could also be reduced if the data collected are showing the same trends and similar magnitude of results.

6.8.6 As a site moves from an operational to decommissioning status, consideration needs to be given to changes in the discharge, taking in to account temporary increases in certain nuclides as clean up is undertaken or the absence of others. The possibility of new fugitive release pathways – e.g. dust / particulate from demolition work being created, also needs to be considered.

6.8.7 Once a site moves in to care and maintenance or a state of quiescence some surveillance monitoring may still be required to meet the objectives of detecting abnormal, fugitive and unauthorised releases and public reassurance. The magnitude of the programme required will be related to the level of clean up undertaken before being put in to quiescence, as this will affect the potential for releases.

# 7 Quality assurance

## 7.1 General Requirements

7.1.1 Organisations undertaking routine radiological monitoring should work within a documented management system, ideally certified to ISO 9001 [Ref 6], using suitable experienced and qualified personnel. This satisfies monitoring principle 10 on meeting quality standards. Documented procedures should be available to cover all aspects of the work.

7.1.2 ***Sampling*** – An audit trail of all samples should be maintained from the point of collection to final analysis, this can be achieved using a robust chain of custody. Samples should be transported to and stored in the laboratory in a secure manner under storage conditions that minimise or eliminate loss or change of the principal constituents under investigation . Samples should be retained to enable future analysis – minimum retention periods shall be agreed in consultation with the regulator.

7.1.3 ***Sample preparation*** - Sample preparation should ensure that a homogeneous sub-sample is taken for analysis. Drying and hand mixing of soils or sediments prior to sub-sampling should be acceptable for gamma spectroscopy where a relatively large sub-sample is used (e.g. 500g). However, drying, grinding and sieving prior to sub-sampling should be carried out where a small sub-sample (e.g. 5g) is to be taken for radiochemical analysis.

7.1.4 ***Analysis*** - Methods should meet the requirements of any relevant international standards, British Standards, MCERTS or other nationally recognised standards. The analytical methods should be adequately validated and controlled such that they are or could be accredited by the United Kingdom Accreditation Scheme (UKAS) (or equivalent) under BS EN ISO/IEC 17025:2005 'General requirements for the competence of testing and calibration laboratories'. Particular attention should be paid to the requirements on method validation, instrument calibration and performance testing. Analytical laboratories should participate in national/international (e.g. NPL) inter-laboratory comparisons (e.g. annually) to assist in quality assurance. Where possible, inter-comparisons should be chosen which relate not only to relevant determinands, but also relevant sample type. Performance criteria should be defined for acceptability of results to satisfy monitoring principle 11, including limits of detection, analysis of standards, analysis turnaround etc.

## 7.2 Training

7.2.1 The experience, training and technical competence of personnel assigned to do the monitoring will directly affect the quality of the data being obtained. Hence only suitably qualified and experienced people (SQEP) should carry out the monitoring, sampling, analysis and data assessment/reporting. Continued competence should be assessed by internal audit and formal SQEP reviews where appropriate. The degree of experience and qualifications required will be matched to the complexity of the analysis being undertaken and level of uncertainty that is acceptable on a result, which will be influenced by whether the site is assessed as lower or higher impact site.

7.2.2 Role profiles defining the required level of education and experience should be produced. The required training and qualifications should be determined to be in accordance with the procedures to be undertaken.

7.2.3 Training should take the form of studying and understanding the techniques/procedures and on the job training to gain experience. The training should be documented with evidence of competence (e.g. independently collecting integrity-assured and traceable samples or conducting a field measurement with the results falling within acceptable Quality Control limits) required before a person's competence is signed off.

7.2.4 Re-training or refresher training should be required if work has not been undertaken for a period greater than 12 months. Where the sampling period is greater than 12 months (e.g. for annual samples) a previously trained and competent person may follow a written procedure to take those samples.

7.2.5 Training should be documented and training records kept and maintained.

### 7.3 Uncertainty

7.3.1 The measurement methods should be reviewed to identify all potential sources of uncertainty. The significant sources of uncertainty should be quantified and the uncertainty components combined at the 95$^{th}$ percentile level of confidence. The measurement uncertainty should be reported with the measurement result.

7.3.2 The generally accepted approach to evaluating and expressing uncertainties in measurements undertaken by testing and calibration laboratories is given in The Guide to the Expression of Uncertainty in Measurement, first published in 1993 by ISO, Geneva. As this is a complex document NPL have produced a guidance note presenting principles and guidance for the estimation of measurement uncertainty [Ref 12].

## 8 Health, safety and environment

8.1 Anyone conducting a monitoring programme must comply with the health and safety arrangements of their organisation and personnel should be competent and trained in relevant health and safety issues. In particular, risk assessments (generic and/or site specific) should be documented and in place and a dynamic risk assessment (at point of work) procedure employed. These risk assessments will need to consider all the hazards likely to be encountered including, but not limited to:

- Tides
- Quick sand
- Rock falls
- Unexploded ordnance
- Wildlife (e.g. snakes, bees)
- Livestock
- Electric fences
- Slopes
- Working near water
- Contamination
- Ionising radiation
- Biological hazards
- Weather (e.g. cold, sunstroke)
- Uneven ground
- Work at heights
- Lone working
- Driving
- Railways/roads
- Ground penetration and contact with electrical cables
- Manual handling
- Sampling equipment e.g. cutting devices

8.2 Control measures should be used to reduce the risk to an acceptable level before starting work. Control measures can be procedural, engineered or personal protective equipment.

8.3 Accidents or near misses should be reported, as defined in organisations' safety procedures, to allow lessons to be learnt and aid in the development of procedures and guidance to avoid future accidents.

8.4 Procedures should be defined for the appropriate action to be taken, if a discreet active item (e.g. stone, plastic fragment, particle) or a localised area of contamination are identified. These will also need to address health and safety requirements and also the responsibility for custody and detailed analytical requirements.

8.5 Procedures should be followed and actions taken where necessary to address bio-security to protect wildlife and farm animals from the spread of diseases (e.g. foot and mouth disease, fungal infections).

8.6 Organisations should take account of the relevant requirements of ISO 14001 including the need to identify the environmental effects of their monitoring programmes (e.g. emissions during driving, use of disposable items, use and disposal of chemicals) and implement measures to minimise these environmental effects. Sites of Special Scientific interest / Natura 2000 sites should be respected.

# 9 Reporting, records, assessment and interpretation

## 9.1 Reporting and records

9.1.1 Reports for verified environmental monitoring results should be produced in a timely manner (as defined in the CEAR for operators or work specification for regulator programmes) so that best use can be made of the data and early indications of changes in the environment can be identified and acted upon.

9.1.2 Reports should include or reference information on the methods used and the quality assurance process. The results should be presented with information on units, uncertainties and detection limits. It should be clearly stated whether the results are decay corrected to the date of sampling.

9.1.3 Procedures should be in place for the early notification of unusual results, particularly those that are unusually high. It may help if a table of “warning levels” is maintained to trigger this consistently. There are various stages where this can occur:

- Directly following sampling in the field, if dose rate monitoring is being undertaken – as would be good practice for samples coming from areas of potentially high activity.
- Following receipt of samples at the laboratory where dose rate readings should be taken.
- Directly following analysis where judgement should be used to determine whether they are significantly above normal environmental levels. This judgement should not only be based on reviewing the actual results, but also take into account knowledge of other factors such as variation in sediment grain size and characteristics at a particular location. Appropriate pre-determined action, trigger or warning levels may be set up to aid in this process.

9.1.4 Records should be kept for a defined period of time (as specified by the regulator), the information should be traceable and retrievable, taking account of changing storage technology.

## 9.2 Assessment and Interpretation

9.2.1 Results should be assessed in the context of the objectives for which the monitoring was designed. For some of these objectives there will be applicable standards with which results should be compared, e.g. Generalised Derived Limits (GDLs) [Ref 13], or a percentage of them (e.g. 10%), for dose related objectives (Objectives A, B). For these it may also be appropriate to undertake dose assessments with the data and compare with dose limits. For others, e.g. public reassurance (Objective E) or assessing background (Objective G), comparison with previous results, action levels (e.g. 3 or 4 standard deviations) and natural backgrounds may be most appropriate. Operators may set criteria for determining what might indicate an abnormal release and what subsequent action(s) should be taken.

9.2.2 Checks on the internal consistency of results can also be undertaken for example, where appropriate and taking account of uncertainties, the sum of the alpha or beta/gamma emitting radionuclides can be compared with total alpha or total beta measurements and consistency of results within decay series can be checked. Data can also be compared with other data sets such as those published in the Radioactivity in the Environment series of reports (RIFE) [e.g. Ref 14].

9.2.3 The assessed level of site impact should be taken into consideration for the degree of interpretation and assessment required. For higher impact sites it may be appropriate to utilise the various statistical approaches available for further assessing results, for example looking at averages and standard deviations, undertaking trend analysis (looking for rising and falling trends) - this could be visual or with software, assessing whether the data are censored (i.e. are limit of detection data truncating the data set so the true distribution is unknown), using a box and whisker approach (i.e. graphically depicting the data through their five-number summaries: sample minimum, lower quartile (Q1), median (Q2), upper quartile (Q3), and sample maximum) or looking for the first arrival of a finite value (rather than Limit of Detection) in a data set. For lower impact sites, simple inspection of tabular or graphical presentation of monitoring results may be sufficient.

# 10 Definitions

**CEAR** – Compilation of Environment Agency Requirements

**Decision threshold** – defined in ISO 11929-7 [Ref 15] as the "the fixed value of the decision quantity (random variable for the decision whether the physical effect to be measured is present or not) by which, when exceeded by the result of an actual measurement of a measurand quantifying a physical effect, it is decided that the physical effect is present". Further guidance on the decision threshold is provided in the Radiological Monitoring Technical Guidance Note 1: Standardised Reporting of Radioactive Discharges for Nuclear Sites [Ref 16].

**Detection limit** – defined in ISO 11929-7 [Ref 15] as the "smallest true value of the measurand that is detectable, with a given probability of error, by the measuring method". Further guidance on the detection limit is provided in the Radiological Monitoring Technical Guidance Note 1: Standardised Reporting of Radioactive Discharges for Nuclear Sites

**Exposure pathway** – The route in the environment through which people or wildlife may become exposed to radioactivity or radiation. For example, inhalation of radionuclides in air, drinking of water containing radionuclides, external radiation from walking over sediments containing radionuclides.

**Indicator** – term used in relation to a sample type that is rapidly responsive to changing activity concentrations.

**MCERTS –** Monitoring Certification Scheme

**Non-nuclear premises** – Premises with an Environmental Permitting Regulations 2010 (EPR 2010) or Radioactive Substances Act 1993 authorisation which is not a nuclear site (e.g. university, hospital, pharmaceutical company).

**Nuclear site** – A site licensed by the Nuclear Installations Inspectorate under the Nuclear Installations Act 1965 and Nuclear Installations Regulations 1971. Also included are tenants on nuclear licensed sites and those sites which would be nuclear licensed sites if Crown Immunity did not apply.

**Representative person** – An individual receiving a dose that is representative of the more highly exposed individuals in the population. This term is equivalent to and replaces the previous concept of the 'average member of the representative person' [Ref 17].

# 11 References


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2. Radioactive Substances Act, 1993
3. Beresford, N., Brown, J., Copplestone, D., Garnier-Laplace, J., Howard, B.J., Larsson, C-M., Oughton, O., Pröhl, G., Zinger, I. (eds.) 2007.D-ERICA: An INTEGRATED APPROACH to the assessment and management of environmental risks from ionising radiation. Description of purpose, methodology and application.
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11. Leonard, K.S. R&D Best Practice Techniques for Environmental Radiological Monitoring. Environment Agency Science report SC030308/SR 2007.
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16. Environment Agency and Scottish Environment Protection Agency. Radiological Monitoring Technical Guidance Note 1: Standardised Reporting of Radioactive Discharges for Nuclear Sites.
17. ICRP (2006). Assessing Dose of the Representative Person for the Purpose of Radiation Protection of the Public and Optimisation of Radiological Protection: Broadening the Process. ICRP Publication 101. *Ann ICRP*, **36,** No 3.


**Table 1:**


1. IAEA Safety Standards Series No. RS G-1.8. Environmental and Source Monitoring for Purposes of Radiation Protection. Safety Guide. IAEA, Vienna, 2005.
2. The Convention for the Protection of the Marine Environment of the North-East Atlantic, Ospar Convention, 1992

3. Treaty on Establishing the European Atomic Energy Commission, Euratom Treaty

**Table 4:**

1. Environment Agency Work Instruction Protocol for Groundwater Quality Sampling (ES006) 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 Ground Waters.
4. ISO 5667 part 18 Water Quality Sampling – Guidance on Sampling Groundwater from contaminated sites.
5. Methodology for Monitoring and Sampling groundwater, NRA R&D note 126.
6. Technical Guidance Note (Monitoring) M5: Routine measurement of gamma air kerma rate in the environment. HMSO, 1995.
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**Table 5**

1. HSE Guidance on Electrical Safety Guidance Note 107

## Table 1 Generic monitoring objectives with guidance/criteria

| Ref | Objective | Description and purpose of monitoring | Current / future discharges | Historic discharges | Regulator | Operator | Guidance and criteria for setting objectives for an environmental radiological monitoring programme |
|---|---|---|---|---|---|---|---|
| A | Assess total representative person (see definitions) dose | Regulators are responsible for ensuring that dose limits from authorised practices are not breached. | ✓ | ✓ | ✓ | - | Objective required for monitoring programme at a site where the dose assessed to be >0.02 mSv $y^{-1}$ for discharges at EPR 2010 / RSA 93 limits from all authorised sources. Once adequate monitoring data become available, these may be used to assess dose and determine whether this objective is required. Objective should be assigned to monitoring of exposure pathways which contribute doses >0.001 mSv $y^{-1}$ to the total dose. |
| B | Assess dose as an operator's performance measure | To be able to determine whether BPM / BAT is being used to minimise the impact on the environment. | ✓ | - | - | ✓ | Assessing dose as a performance measure is only likely to be informative to an operator where the dose assessed is >0.02 mSv $y^{-1}$ for discharges at EPR 2010 / RSA 93 limits. Once adequate monitoring data become available, these may be used to assess dose and determine whether this objective is required. Objective should be assigned to monitoring of exposure pathways which contribute doses > 0.001 mSv $y^{-1}$ to the total dose. |
| C | Assess total impact on wildlife (e.g. dose) | Combines with Objective A to further address the site's impact, with specific effects on wildlife being assessed. | ✓ | ✓ | ✓ | - | Objective required for monitoring programme at a site where the dose assessed to be >10 µGy $h^{-1}$ (annual average) for discharges at EPR 2010 / RSA 93 limits from all authorised sources. Once adequate monitoring data become available, these may be used to assess dose and determine whether this objective is required. Objective should be assigned to monitoring of exposure pathways which contribute doses >1 µGy $h^{-1}$ (annual average) to the total dose. |
| D | Assess impact on wildlife as an operator's performance measure (dose) | As with Objective B to be able to determine whether BPM / BAT is being used to minimise the impact on wildlife. | ✓ | - | - | ✓ | Assessing the impact on wildlife as a performance measure is only likely to be informative to an operator where the dose assessed is >10 µGy $h^{-1}$ (annual average) for discharges at EPR 2010 / RSA 93 limits. Once adequate monitoring data become available, these may be used to assess dose and determine whether this objective is required. Objective should be assigned to monitoring of exposure pathways which contribute doses >1 µGy $h^{-1}$ (annual average) to the total dose. |
| E | Provide public and stakeholder reassurance | Regulators to provide reassurance to the public | ✓ | ✓ | ✓ | (✓) | The need for this objective will be dependent upon on-going and emerging concerns. The extent to which the objective will be assigned to monitoring of different exposure pathways should be proportionate to the scale of the concerns and the potential impact. This objective should generally not be assigned to a particular exposure pathway where the dose is ≤ 0.001 mSv $y^{-1}$. |

**Table 1 Continued**

| Ref | Objective | Description and purpose of monitoring | Current / future discharges | Historic discharges | Regulator | Operator | Guidance and criteria for setting objectives for an environmental radiological monitoring programme |
|---|---|---|---|---|---|---|---|
| F | Check / compli-mentary monitoring | Allows results comparison, designed to identify any sampling / monitoring / analytical problems and allow investigations to be instigated. Consistency of results | ✓ | ✓ | ✓ | (✓) | This objective will generally be required for each site which has a routine environmental radiological monitoring programme. Normally, elements of the regulator's programme provide a check on the operator's programme. However, for foodstuffs in England and Wales, the Food Standards Agency's monitoring programme may be considered to be the main programme and elements of the operator's provide a check on the FSA programme. The elements of the programme assigned as check monitoring should also be designed for the same objective as the main programme to ensure the results can be compared. Overall, check monitoring should provide about a 10% check on the main programme, taking account the number of locations and frequency of monitoring in the main programme. |
| G | Assess background (very far field) | Provides info on background conditions against which to assess impact of site operations. | (✓) | ✓ | ✓ | - | This objective is generally satisfied by national monitoring programmes required by the European Commission. The objective should be assigned to monitoring locations which are beyond the range of the detectable impact of sources. |
| H | Assess long term trends (Indicator) | Provide information on changes to the environment over time. | ✓ | ✓ | ✓ | ✓ | The need for this objective will depend upon the observed or potential rate of change of environmental concentrations, for example due to variable discharge profile (e.g. batch processes), half-life of radionuclide and dynamic environmental process. The objective should be assigned to monitoring parts of the environment which accumulate or integrate radionuclides (e.g. seaweed). Samples should be taken from the same locations for a meaningful temporal comparison of the results to be made [Ref 1]. If modelled/measured activity concentrations were close to background/limit of detection, monitoring for this objective would be unlikely to be warranted. |
| I | Comply with international obligations | To gather information to comply with international requirements (e.g. OSPAR, Euratom Articles 35/36). | ✓ | ✓ | ✓ | ✓ (not reported under Article 36) | Objectives assigned to monitoring programmes or elements of programmes which are required to comply with international agreements. |

## Table 1 Continued

| Ref | Objective | Description and purpose of monitoring | Current / future discharges | Historic discharges | Regulator | Operator | Guidance and criteria for setting objectives for an environmental radiological monitoring programme |
|---|---|---|---|---|---|---|---|
| J | Detect abnormal, fugitive and unauthorised releases (Indicator) | To provide an early indication of an abnormal release.<br>To pick up any unaccounted for releases – could be from fugitive emissions or from a process with an unexpected consequence. | ✓ | - | - | ✓ | Objective required where there is the potential for abnormal or fugitive releases. This objective should be assigned to elements of the monitoring programme which are sensitive to change and have a rapid response so that they can provide a means of early detection of such an abnormal release.<br>Instrumentation to detect abnormal releases on for instance stacks may provide better early warning/information and preclude the need for this objective. |
| K | Understand / monitor behaviour of radio-nuclides in the environment | Wide ranging objective looking at spatial distribution and temporal variations. Model verification could be considered if information gained could be back fitted and linked to models (e.g. retrospective dose assessment. | ✓ | ✓ | ✓ | ✓ | This objective is likely to be assigned to sites with the largest environmental impact to ensure that the main source – pathway – receptor routes have been identified and the scientific basis of the programme remains acceptable and any constraints on the data are understood. The objective should only be assigned to elements of the monitoring programme where there are detectable activity concentrations (i.e. greater than limit of detection). Sample types and locations will need to be selected to provide information on spatial distribution, extent of dispersion, re-concentration and changes in environmental behaviour of radionuclides. They will also need to be compatible with models to allow model verification. |

## Table 2 Sample types which can be used to meet objectives

| Ref | Objectives | Sample / Monitoring type | |
|---|---|---|---|
| A | Assess total representative person dose | Dose Rate Monitoring (Terrestrial)<br>Dose Rate Monitoring (Inter-tidal/marine)<br>High Volume Air Sampling<br>Water (Tap, surface, groundwater)<br>Grass (dose surrogate)<br>Landfill leachates<br>Sewage/sludges<br>Sediment – Estuary/coastal freshwater<br>Seaweed | Milk and dairy products<br>Meat & meat products<br>Poultry, Eggs<br>Fruit & Vegetables<br>Wildlife/Game<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater<br>Freshwater weed |
| B | Assess dose as an operator's performance measure | Dose Rate Monitoring (Terrestrial)<br>Dose Rate Monitoring (Inter-tidal/marine)<br>High Volume Air Sampling<br>Water (Tap, surface, groundwater)<br>Grass (dose surrogate)<br>Landfill leachates<br>Sewage/sludges<br>Sediment – Estuary/coastal freshwater<br>Seaweed | Milk and dairy products<br>Meat & meat products<br>Poultry, Eggs<br>Fruit & Vegetables<br>Wildlife/Game<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater<br>Freshwater weed |
| C | Assess total impact on wildlife (dose) | Dose Rate Monitoring (Terrestrial)<br>Dose Rate Monitoring (Inter-tidal/marine)<br>Water (Tap, surface, groundwater)<br>Soil<br>Sediment – Estuary/coastal freshwater<br>Seawater collected from shore | Wildlife/Game<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater |
| D | Assess impact on wildlife as an operator's performance measure (dose) | Dose Rate Monitoring (Terrestrial)<br>Dose Rate Monitoring (Inter-tidal/marine)<br>Water (Tap, surface, groundwater)<br>Soil<br>Sediment – Estuary/coastal freshwater<br>Seawater collected from shore | Wildlife/Game<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater |

## Table 2 Continued

| Ref | Objectives | Sample / Monitoring type | |
|---|---|---|---|
| E | Provide public and stakeholder reassurance | Dose Rate Monitoring (Terrestrial) – also, workforce reassurance<br>Dose Rate Monitoring (Inter-tidal/marine)<br>Contamination monitoring (Inter-tidal/marine)<br>High Volume Air Sampling<br>Passive Shades<br>Total Deposition<br>Water (Tap, surface, groundwater)<br>Soil<br>Grass<br>Landfill leachates – also workforce reassurance (landfill operatives)<br>Sewage/sludges – also workforce reassurance (public STW workers)<br>Sediment – Estuary/coastal freshwater<br>Seawater collected from shore<br>Seaweed | Milk and dairy products<br>Meat & meat products<br>Poultry, Eggs<br>Fruit & Vegetables<br>Wildlife/Game<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater<br>Freshwater weed |
| F | Check / complementary monitoring | Dose Rate Monitoring (Terrestrial)<br>Dose Rate Monitoring (Inter-tidal/marine)<br>Contamination monitoring (Inter-tidal/marine)<br>High Volume Air Sampling<br>Total Deposition<br>Water (Tap, surface, groundwater)<br>Soil<br>Grass<br>Landfill leachates<br>Sewage/sludges<br>Sediment – Estuary/coastal freshwater<br>Seawater collected from shore<br>Seaweed | Milk and dairy products<br>Meat & meat products<br>Poultry, Eggs<br>Fruit & Vegetables<br>Cereal (Crops<br>Wildlife/Game<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater<br>Freshwater weed |

## Table 2 Continued

| Ref | Objectives | Sample / Monitoring type | |
|---|---|---|---|
| G | Assess background (very far field) | Dose Rate Monitoring (Terrestrial)<br>Dose Rate Monitoring (Inter-tidal/marine)<br>High Volume Air Sampling<br>Total Deposition<br>Water (Tap, surface, groundwater)<br>Soil<br>Grass<br>Sewage/sludges<br>Sediment – Estuary/coastal freshwater<br>Seawater collected from shore<br>Seaweed | Milk and dairy products<br>Meat & meat products<br>Poultry, Eggs<br>Fruit & Vegetables<br>Cereal (Crops)<br>Wildlife/Game<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater<br>Freshwater weed |
| H | Assess long term trends (Indicator) | Dose Rate Monitoring (Terrestrial)<br>Dose Rate Monitoring (Inter-tidal/marine)<br>High Volume Air Sampling<br>Passive shades<br>Total Deposition<br>Water (Tap, surface, groundwater)<br>Soil<br>Grass<br>Landfill leachates<br>Sewage/sludges<br>Sediment – Estuary/coastal freshwater<br>Seawater collected from shore<br>Seaweed | Milk and dairy products<br>Meat & meat products<br>Poultry, Eggs<br>Fruit & Vegetables<br>Cereal (Crops)<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater<br>Freshwater weed |
| I | Comply with international obligations | High Volume Air Sampling<br>Total Deposition<br>Water (Tap, surface, groundwater)<br>Seawater collected from shore | Milk and dairy products<br>Meat & meat products<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater |

## Table 2 Continued

| Ref | Objectives | Sample / Monitoring type | |
|---|---|---|---|
| J | Detect abnormal, fugitive and unauthorised releases (Indicator) | Dose Rate Monitoring (Terrestrial)<br>Dose Rate Monitoring (Inter-tidal/marine)<br>Contamination monitoring (Inter-tidal/marine)<br>High Volume Air Sampling<br>Passive Shades<br>Total Deposition<br>Water (Tap, surface, groundwater)<br>Grass<br>Landfill leachates<br>Sewage/sludges – for operators being done as part of clearance, regulators may do for public STW<br>Sediment – Estuary/coastal freshwater<br>Seawater collected from shore – scale from pipes<br>Seaweed | Milk and dairy products<br>Fruit & Vegetables<br>Wildlife/Game<br>Crustaceans & Molluscs – Marine and freshwater<br>Freshwater weed |
| K | Understand / monitor behaviour of radio-nuclides in the environment | Dose Rate Monitoring (Terrestrial) – also, workforce reassurance<br>Dose Rate Monitoring (Inter-tidal/marine)<br>Contamination monitoring (Inter-tidal/marine)<br>High Volume Air Sampling<br>Passive Shades<br>Total Deposition<br>Water (Tap, surface, groundwater)<br>Soil – only relevant for dynamic environments<br>Grass<br>Sewage/sludges<br>Sediment – Estuary/coastal freshwater<br>Seawater collected from shore<br>Seaweed | Milk and dairy products<br>Meat & meat products<br>Fruit & Vegetables<br>Wildlife/Game<br>Fish – Marine and freshwater<br>Crustaceans & Molluscs – Marine and freshwater<br>Freshwater weed |

## Table 3 – Guidance on what to monitor, where and how often

This table indicates which programme is meeting an objective – i.e. regulator or operator through the use of prefixes R and O.
Where different samples/monitoring would be required to meet different objectives e.g. for the regulator programme, assess total representative person dose (Objective A) and assess background (Objective G) the components of the programme are indicated as R1 and R2.
Where the same samples/monitoring or a subset of these can be used to fulfil other objectives this is indicated by putting the objective code in brackets. For example for 3.4 in Table 3 "provide public and stakeholder reassurance" (Objective E) could be a sub-set of the "assess total representative person dose" hence for 3.4 of Table 3 against Objective E this is indicated as (R1). This does not indicate priority between the objectives, but is based on the objective for which the greatest number of samples is required.
For the assess background (very far field objective ) (Objective G) if there is a national programme being undertaken there may be no need to take additional background samples for a particular site, hence the lower value of the range is zero.
Not all the sample/monitoring types in Table 3 will apply to every situation, for example sites with HVAS may not deploy passive shades and vice versa.
The "Differences for Historical Releases" column indicates whether a different sampling strategy would be required if historical discharges were being routinely monitored rather than current releases.

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.1** Dose Rate Monitoring (Terrestrial) | Assess total representative person dose | (R1) | $\mu Svh^{-1}$ $\mu Svy^{-1}$ | 1-4 At location of max predicted dose and others determined from habit surveys [Discharges and direct radiation] | Continuous | 1-4 continuous | **<u>Operator</u>** **Continuous 5-22** **Or 4 - 120 spot** **<u>Regulator</u>** **Continuous 1 – 10** **Or 4 - 120.2 spot** | No difference, also based on previous monitoring / knowledge / habit surveys |
| | Assess dose as an operator's performance measure | O1 | $\mu Svh^{-1}$ $\mu Svy^{-1}$ | 1-10 At location of max predicted dose and others determined from habit surveys [Discharges and direct radiation] | Continuous &/or monthly- quarterly spot measurement | 1-10 continuous or 4-120 spot | | As above |
| | Assess total impact on wildlife (e.g. dose) | (R1) | $\mu Gyh^{-1}$ | 1-4 Targeted to sensitive habitats | Continuous | 1-4 continuous | | No difference |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | (O1) | $\mu Gyh^{-1}$ | 1-10 Targeted to sensitive habitats | Continuous &/or monthly -quarterly spot measurement | 1-10 continuous or 4-120 spot | | No difference |
| | Provide public & stakeholder reassurance | R1 | $\mu Svh^{-1}$ $\mu Svy^{-1}$ | 1-10 Targeting large population centres – maybe more distant &/or Max dose | Continuous &/or monthly- quarterly spot measurement | 1-10 continuous or 4-120 spot | | No difference |
| | Provide workforce reassurance | (O1) | $\mu Svh^{-1}$ $\mu Svy^{-1}$ | 1-4 around site perimeter &/or Max dose | Continuous &/or monthly- quarterly spot measurement | 1-4 continuous or 4-48 spot | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.1 cont.** Dose Rate Monitoring (Terrestrial) | Check/complementary monitoring | (R1) (O1) | μSvh$^{-1}$ μSvy$^{-1}$ | Max dose | Continuous &/or quarterly – annually spot measurement | 1 continuous or 1-4 spot | | No difference |
| | Assess background (very far field) | R2 | μSvh$^{-1}$ μSvy$^{-1}$ | 1-2 background locations or done as part of a national programme e.g. 20-50km survey grid | 10 years | 0-2 per 10 years spot | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | μSvh$^{-1}$ μSvy$^{-1}$ | Max dose | Continuous &/or annual spot measurement | 1 continuous or 1 spot | | No difference |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | μSvh$^{-1}$ μSvy$^{-1}$ | 4-12 around site perimeter (Less for coastal location) Covered by emergency arrangements | Continuous – instrument based | 4-12 continuous | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | μSvh$^{-1}$ μSvy$^{-1}$ | Max dose | Quarterly to annually Spot measurement [Trigger to look at other monitoring] | 1-4 spot | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.2** Dose Rate Monitoring (Inter-tidal/marine) | Assess total representative person dose | (R1) | μSvh$^{-1}$ μSvy$^{-1}$ | 1-4 At location of max predicted dose and others determined from habit surveys/modelling [Discharges and direct radiation] | Spot measurement monthly – quarterly – continuous would be good, but prevented by practicalities. | 4-48 | **Operator** **4-120** **Regulator** **4.1-242** | No difference, also based on previous monitoring / knowledge / habit surveys |
| | Assess dose as an operator's performance measure | O1 | μSvh$^{-1}$ μSvy$^{-1}$ | 1-10 At location of max predicted dose and others determined from habit surveys/modelling [Discharges and direct radiation] | Spot measurement monthly – quarterly – continuous would be good, but prevented by practicalities. | 4-120 | | No difference |
| | Assess total impact on wildlife (e.g. dose) | (R1) | μGyh$^{-1}$ | 1-4 Targeted to sensitive wildlife | Spot measurement monthly – quarterly – continuous would be good, but prevented by practicalities. | 4-48 | | No difference |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | (O1) | μGyh$^{-1}$ | 1-10 Targeted to sensitive wildlife | Spot measurement monthly – quarterly – continuous would be good, but prevented by practicalities. | 4-120 | | No difference |
| | Provide public & stakeholder reassurance | R1 | μSvh$^{-1}$ μSvy$^{-1}$ | 1-20 Targeting non-critical habits, further afield | Spot measurement monthly – quarterly – continuous would be good, but prevented by practicalities. | 4-240 | | No difference |
| | Check/complementary monitoring | (R1) (O1) | μSvh$^{-1}$ μSvy$^{-1}$ | 10% of locations (range of doses) i.e. 1-3 | Spot measurement quarterly - annually– continuous would be good, but prevented by practicalities. | 4-12 | | No difference |
| | Assess background (very far field) | R2 | μSvh$^{-1}$ μSvy$^{-1}$ | 1-10 remote locations (better achieved by analysing natural contributions at the site) | 5-10 yearly | 1 per 10 years - 2 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.2 cont.** Dose Rate Monitoring (Inter-tidal/marine) | Assess long term trends (indicator) | (R1) (O1) | $\mu Svh^{-1}$ $\mu Svy^{-1}$ | 1-3 locations, Max dose, both directions from site | Spot measurement annual – continuous would be good, but prevented by practicalities. | 1-3 | | No difference |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | $\mu Svh^{-1}$ $\mu Svy^{-1}$ | 1-3 locations, Max dose, both directions from site | Spot measurement quarterly - annually [Trigger to look at other monitoring] | 1-12 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range (kmy$^{-1}$) | Total survey length (kmy$^{-1}$) | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.3** Contamination monitoring (Inter-tidal/marine) | Provide public & stakeholder reassurance | R1 | Cps<br>Defined action level<br>Conversion factor to dose | 1-20 km of beach / inter-tidal areas (maybe broken into stretches), targeting occupied areas based on habit surveys and predicted concentrations | Quarterly – annually | 1-80 | **Operator**<br>**4-72**<br><br>**Regulator**<br>**1-80** | Targeting on known areas of contamination |
| | Check/complementary monitoring | (R1)<br>(O1) | Cps<br>Defined action level<br>Conversion factor to dose | 10% of locations<br>i.e. 1-2 | Annually | 1-2 | | As above |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O1 | Cps<br>Defined action level<br>Conversion factor to dose | 1-6 km of beach/inter-tidal areas (maybe broken into stretches).<br>Close to pipeline to modelled area of maximum impact. Both directions from site | Monthly – Quarterly | 4-72 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1)<br>(O1) | cps | 1km of beach at areas of maximum contamination, both directions from site | Annually | 2 | | Targeting maximum areas of known areas of contamination<br>Suspect environmental processes causing change |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.4** High Volume Air Sampling | Assess total representative person dose | R1 | $Bqm^{-3}$ | 1-4 Population centres with highest predicted air concentration – reflect wind-rose | Continuous – quarterly campaigns, monthly filter changes, monthly to quarterly analysis batches | 4-48 | **Operator** **4-48** **48-144 limited nuclides** **Regulator** **4-48** **+ 1-120 part of national programme for background and international obligations.** | Prediction of air concentration from source of contamination and re-suspension |
| | Assess dose as an operator's performance measure | O1 | $Bqm^{-3}$ | 1-4 Population centres with highest predicted air concentration – reflect wind-rose or 1-4 around perimeter | Continuous – quarterly campaigns, monthly filter changes, monthly to quarterly analysis batches | 4-48 | | Prediction of air concentration from source of contamination and re-suspension |
| | Provide public & stakeholder reassurance | (R1) | $Bqm^{-3}$ | 1-4 Targeting large population centres – maybe more distant &/or Max concentration | Continuous – quarterly campaigns, monthly filter changes, monthly to quarterly analysis batches | 4-48 | | No difference |
| | Check/complementary monitoring | (R1) (O1) | $Bqm^{-3}$ | Max air concentration | Quarterly campaign, Annually – 3 years | 1 per 3 years - 1 | | No difference |
| | Assess background (very far field) | (R2) | $Bqm^{-3}$ | 1-2 remote locations or as part of a national programme. Could be done on a campaign basis. | Continuous – monthly filter changes, monthly to annual bulks [Dependent on conditions for change frequency] | 0-24 | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | $Bqm^{-3}$ | Max air concentration | Continuous – monthly filter changes, monthly to annual bulks [Dependent on conditions for change frequency] | 1-12 | | No difference Looking at resuspension |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.4 cont.**<br>High Volume Air Sampling | Comply with international obligations | R2 | $Bqm^{-3}$ | [Total of 1-10 remote locations in national programme] | Continuous – monthly filter changes monthly to annual bulks<br>[Dependent on conditions for change frequency] | 1-120 | | NA Check obligations |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | $Bqm^{-3}$<br>$Bqkg^{-1}$ | 4-12 around site perimeter<br>(Less for coastal location) | Continuous – monthly filter changes monthly bulks<br>[Dependent on conditions for change frequency]<br>Limited indicator nuclides | 48-144 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1)<br>(O1) | $Bqm^{-3}$ | Max concentration | Continuous – monthly filter changes monthly bulks | 12 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.5** Passive Shades | Provide public & stakeholder reassurance | R1 | Bq/shade | 1-4 Targeting large population centres – maybe more distant &/or Max concentration and 1-4 around site perimeter | Continuous sampling – monthly to annual analysis (could have more frequent sample change) | 2-96 | **Operator** **48-144** **Regulator** **2-96** | Target on source of contamination – eg land contamination, sea to land transfer, re-suspension |
| | Assess long term trends (indicator) | (R1) (O1) | Bq/shade | At point of max concentration | Continuous sampling quarterly - annually analysis | 4-12 | | No differences |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O1 | Bq/shade | 4-12 around site perimeter (Less for coastal location) | Continuous sampling – monthly analysis | 48-144 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | Bq/shade | At point of max concentration | Continuous sampling – quarterly - annually analysis | 1-4 | | No differences |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.6**<br>Total Deposition | Provide public & stakeholder reassurance | R1 | $Bql^{-1}$<br>$Bqm^{-2}$<br>$Bqm^{-3}$ | 1-4 Population centres with highest predicted deposition – reflect wind-rose (could be on site or at perimeter) | Continuous collection<br>monthly to quarterly bulks<br>Annual analysis on some radionuclides | 4-48 | **Operator**<br>**1-8**<br>**48-144 limited nuclides**<br>**Regulator**<br>**4-48**<br>**+ 1-120 part of national programme for background and international obligations.** | Target on source of contamination – eg land contamination, sea to land transfer, re-suspension |
| | Check/complementary monitoring | O1<br>(R1) | $Bql^{-1}$<br>$Bqm^{-2}$<br>$Bqm^{-3}$ | 1-2 locations including point of maximum deposition | Continuous collection<br>Quarterly to annual bulks | 1-8 | | No difference |
| | Assess background (very far field) | (R2) | $Bql^{-1}$<br>$Bqm^{-2}$<br>$Bqm^{-3}$ | 1-2 remote locations or done as part of a national programme. | Continuous collection<br>Quarterly to annual bulks | 0-8 | | No difference |
| | Assess long term trends (indicator) | (R1)<br>(O1) | $Bql^{-1}$<br>$Bqm^{-2}$<br>$Bqm^{-3}$ | Point of maximum deposition | Continuous collection<br>Quarterly to annual bulks | 1-4 | | No difference |
| | Comply with international obligations | R2 | $Bql^{-1}$<br>$Bqm^{-2}$<br>$Bqm^{-3}$ | [Total of 1-10 remote locations in national programme] | Continuous collection<br>Monthly to annual bulks | 1-120 | | NA |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | $Bql^{-1}$<br>$Bqm^{-2}$<br>$Bqm^{-3}$ | 4-12 around site perimeter<br>(Less for coastal location) | Continuous collection<br>monthly bulks<br>Limited indicator nuclides | 48-144 limited nuclides | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1)<br>(O1) | $Bql^{-1}$<br>$Bqm^{-2}$<br>$Bqm^{-3}$ | Point of maximum deposition | Continuous collection<br>Quarterly to annual bulks | 1-4 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.7** Water (Tap, surface, groundwater) | Assess total representative person dose | R1 | $Bql^{-1}$ $Bqm^{-3}$ | 1-4 Sources of drinking water for major populations (e.g. taps, reservoirs, rivers, groundwater) plus local water supplies (well, runoff/rainwater, boreholes), based on habit surveys. Also sources for irrigation/cattle drinking water | Quarterly to annually Depending on source Composite bulk for higher doses | 1-16 | **Operator** **2-20** **4-120 limited nuclides** **Regulator** **2-20** **+ 80-240 part of national programme for background and international obligations.** | Could be many more borehole locations for groundwater monitoring of a known contaminated plume. Take account of location of source of contamination |
| | Assess dose as an operator's performance measure | O1 | $Bql^{-1}$ $Bqm^{-3}$ | 1-4 Sources of drinking water for major populations (e.g. taps, reservoirs, rivers, groundwater) plus local water supplies (well, runoff/rainwater, boreholes), based on habit surveys. Also sources for irrigation/cattle drinking water | Quarterly to annually Depending on source Composite bulk for higher doses. | 1-16 | | As above |
| | Assess total impact on wildlife (e.g. dose) | R2 | $Bql^{-1}$ $Bqm^{-3}$ | Water courses with sensitive wildlife/ecosystem | Quarterly to annually Depending on source Composite bulk for higher doses | 1-4 per ecosystem | | No difference |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | O2 | $Bql^{-1}$ $Bqm^{-3}$ | Water courses with sensitive wildlife/ecosystem | Quarterly to annually Depending on source Composite bulk for higher doses | 1-4 per ecosystem | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.7 cont.** Water (Tap, surface, groundwater) | Provide public & stakeholder reassurance | (R1) | $Bql^{-1}$ $Bqm^{-3}$ | 1-10 Sources of drinking water for major populations (eg taps, reservoirs, rivers, groundwater) plus local water supplies (well, runoff/rainwater, boreholes), based on habit surveys. Also sources for irrigation/cattle drinking water | Annually Depending on source Composite bulk for higher doses | 1-10 | | Could be many more borehole locations for groundwater monitoring of a known contaminated plume. Take account of location of source of contamination |
| | Check/complementary monitoring | (R1) (O1) | $Bql^{-1}$ $Bqm^{-3}$ | 10 % check i.e. 1 location | Annually – 3 yearly | 1 per 3 years - 1 | | No difference |
| | Assess background (very far field) | (R3) | $Bql^{-1}$ $Bqm^{-3}$ | 1- 10 remote locations. Upstream. (reflect geology and water course type) | Annually Establish and keep check on less frequently | 1-10 | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | $Bql^{-1}$ $Bqm^{-3}$ | 1 each of water types based on habit surveys. | Annual (rivers maybe more frequent) | 1 per water course, rivers more often | | No difference |
| | Comply with international obligations | R3 | $Bql^{-1}$ $Bqm^{-3}$ | 20 – 60 remote locations for whole UK. (reflect geology and water course type) Based on catchments/populations | Quarterly | 80-240 | | NA |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O3 | $Bql^{-1}$ $Bqm^{-3}$ | 1-10 downstream based on site hydrology. Due to dilution not a good indicator, except for ground water boreholes | Monthly-quarterly Depending on flow rate Limited radionuclides | 4-120 limited nuclides | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | $Bql^{-1}$ $Bqm^{-3}$ | 1 each of water types based on habit surveys. | Annual (rivers maybe more frequent) | 1 per water course, rivers more often | | Could be many more borehole locations for groundwater monitoring of a known contaminated plume. Take account of location of source of contamination |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.8** Milk and dairy products | Assess total representative person dose | R1 | $Bql^{-1}$ | 1-4 local milk producers reflecting modelled concentrations and wind-rose. | Monthly – quarterly analysis – sampling could be weekly [Nuclide dependent i.e. $^{131}I$ may be required more frequently] Needs to be all year round to take account of silage consumption during winter. | 4-48 | **<u>Operator</u>** **4-48** **6-24 limited nuclides** **<u>Regulator</u>** **5-88** **+ 420 as part of national programme for background and international obligations.** | Based on habit surveys of where cows grazing contaminated land eg sea to land transfer, sea-washed pastures. |
| | Assess dose as an operator's performance measure | O1 | $Bql^{-1}$ | 1-4 local milk producers reflecting modelled concentrations and wind-rose. | Monthly – quarterly [Nuclide dependent i.e. $^{131}I$ may be required more frequently] Needs to be all year round to take account of silage consumption during winter | 4-48 | | As above |
| | Provide public & stakeholder reassurance | R2 | $Bql^{-1}$ | 1-10 local producers from habit surveys e.g. local dairies, markets, producers from habit surveys and more distant farms (5-10km) | Quarterly – annual spot or bulk Nuclide dependent i.e. $^{131}I$ may be required more frequently | 1-40 | | As above |
| | Check/complementary monitoring | (R1) (O1) | $Bql^{-1}$ | 10% check i.e. 1 location | Monthly-Annually | 1-12 | | No difference |
| | Assess background (very far field) | (R3) | $Bql^{-1}$ | 1-2 remote milk producers or done as part of a national programme e.g. – supermarket milk | Quarterly – annual Nuclide dependent | 0-8 | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | $Bql^{-1}$ | 1-2 milk producers based on wind-rose (difficult to achieve with changes in farming practices) | Annual | 1-2 | | Based on max from knowledge, habit surveys |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.8 cont.** Milk and dairy products | Comply with international obligations | R3 | $Bql^{-1}$ | Up to 35 locations for Great Britain | Weekly sampling. Monthly to annual bulks for analysis | Up to 420 | | NA |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | $Bql^{-1}$ | 1-4 local milk producers reflecting modelled concentrations and wind-rose. | Monthly whilst cows grazing in field [Limited nuclides] | 6-24 limited nuclides (based on 6 months grazing) | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | $Bql^{-1}$ | 1 -2 milk producers based on wind-rose (difficult to achieve with changes in farming practices) | Annual | 1-2 | | Based on max from knowledge, habit surveys |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.9**<br>Meat & meat products | Assess total representative person dose | R1 | Bq kg$^{-1}$ wet | 0-4 local producers and food types reflecting modelled concentrations and wind-rose. | Quarterly – annually | 0-16 | **Operator**<br>**0-16**<br>**Regulator**<br>**0-32**<br>**Or included in up to 5 as part of national programme for background** | Based on habit surveys of where animals grazing contaminated land eg sea to land transfer, sea-washed pastures. |
| | Assess dose as an operator's performance measure | O1 | Bq kg$^{-1}$ wet | 0-4 local producers and food types reflecting modelled concentrations and wind-rose. | Quarterly – annually | 0-16 | | As above |
| | Provide public & stakeholder reassurance | R2 | Bq kg$^{-1}$ wet | 0-4 local producers and food types from habit surveys e.g. local farm shops producers from habit surveys and more distant farms (5-10km) | Quarterly – annual | 0-16 | | As above |
| | Check/complementary monitoring | (R1)<br>(O1) | Bq kg$^{-1}$ wet | 0-2 local producers and food types<br>10% check | Annually | 0-2 | | No difference |
| | Assess background (very far field) | R3 | Bq kg$^{-1}$ wet | 0-2 remote meat producers and food types or done as part of a national programme e.g. from farms or markets or indirectly through mixed diet programme. | Annual | 0-2 | | No difference |
| | Assess long term trends (indicator) | (R1)<br>(O1) | Bq kg$^{-1}$ wet | 0-1 meat producer and food type based on wind-rose (difficult to achieve with changes in farming practices) | Annual | 0-1 | | Based on max from knowledge, habit surveys |
| | Understand/monitor behaviour of radionuclides in the Food/environment | (R1)<br>(O1) | Bq kg$^{-1}$ wet | 0-1 meat producer and food type based on wind-rose (difficult to achieve with changes in farming practices) | Annual | 0-1 | | Based on max from knowledge, habit surveys |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.10** Poultry, Eggs | Assess total representative person dose | R1 | Bq kg$^{-1}$ wet | 1-4 local producers and food types reflecting modelled concentrations and wind-rose. | Quarterly – annually | 1-16 | **<u>Operator</u>** **1-16** **<u>Regulator</u>** **2-32** **2+ as part of a national programme for backgrounds** | Based on habit surveys of where poultry scavenging on contaminated land eg sea to land transfer, sea-washed pastures. |
| | Assess dose as an operator's performance measure | O1 | Bq kg$^{-1}$ wet | 1-4 local producers and food types reflecting modelled concentrations and wind-rose. | Quarterly – annually | 1-16 | | As above |
| | Provide public & stakeholder reassurance | R2 | Bq kg$^{-1}$ wet | 1-4 local producers and food types from habit surveys e.g. local farm shops producers from habit surveys and more distant farms (5-10km) | Quarterly – annual | 1-16 | | As above |
| | Check/complementary monitoring | (R1) (O1) | Bq kg$^{-1}$ wet | 1-2 local producers and food types 10% check | Annually | 1-2 | | No difference |
| | Assess background (very far field) | R3 | Bq kg$^{-1}$ wet | 1-2 remote producers and food types or done as part of a national programme e.g. – supermarket | Annually | 0-2 | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | Bq kg$^{-1}$ wet | 1 local producer and food type based on wind-rose (difficult to achieve with changes in farming practices) | Annual | 1 | | Based on max from knowledge, habit surveys |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.11** Fruit & Vegetables | Assess total representative person dose | (R1) | Bq $kg^{-1}$ wet | 1-4 local producers and food types (root veg, green veg, fruit, free foods) based on habit surveys and max deposition | Annual at point of harvest | 1-4 | **Operator** **1-4** **Regulator** **1-14** **+ ~50 as part of national programme for background** | No difference |
| | Assess dose as an operator's performance measure | O1 | Bq $kg^{-1}$ wet | 1-4 local producers and food types (root veg, green veg, fruit, free foods) based on habit surveys and max deposition | Annual at point of harvest | 1-4 | | No difference |
| | Provide public & stakeholder reassurance | R1 | Bq $kg^{-1}$ wet | 1-10 local producers and food types (root veg, green veg, fruit, free foods) based on habit surveys and max deposition | Annual at point of harvest | 1-10 | | No difference Free foods |
| | Check/complementary monitoring | (R1) (O1) | Bq $kg^{-1}$ wet | 1-2 local producers and food types 10% check | Annual – 3 yearly | 1 per 3 years - 2 | | No difference |
| | Assess background (very far field) | R2 | Bq $kg^{-1}$ wet | 1-4 local producers and food types (root veg, green veg, fruit, free foods) or done as part of a national programme | Annual – 3 yearly | 0 -4 | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | Bq $kg^{-1}$ wet | 1-4 local producers and food types (root veg, green veg, fruit, free foods) Max concentration | Annually at point of harvest | 1-4 | | No difference |
| | Understand/monitor behaviour of radionuclides in the Food/environment | (R1) (O1) | Bq $kg^{-1}$ wet | 1-4 local producers and food types (root veg, green veg, fruit, free foods) Max concentration | Annually at point of harvest | 1-4 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.12** Cereal (Crops) | Check/complementary monitoring | (R1) O1 | Bq $kg^{-1}$ wet? | 1-2 local producers and food types 10% check | Annual – 3 yearly | 1 per 3 years - 2 | **Operator** **0-2** **Regulator** **1-2** | No difference |
| | Assess background (very far field) | R2 | Bq $kg^{-1}$ wet? | 1-2 remote producers and food types or done as part of a national programme e.g. from farms or markets. | Annual – 3 yearly | 0 -2 | | No difference |
| | Assess long term trends (indicator) | R1 | Bq $kg^{-1}$ wet? | 1 producer & crop (highest concentration) | Annually at point of harvest | 1 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.13**<br>Soil | Assess total impact on wildlife (e.g. dose) | R1 | Bq $kg^{-1}$ dry<br>Wet /dry ratio | 1-5 targeted to sensitive wildlife habitats and max concentrations | Annually | 1-5 | **Operator**<br>**1-5**<br><br>**Regulator**<br>**1-5**<br>**+ 150 part of national programme for background every 10 years** | No difference |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | O1 | Bq $kg^{-1}$ dry<br>Wet /dry ratio | 1-5 targeted to sensitive wildlife habitats and max concentrations | Annually | 1-5 | | No difference |
| | Provide public & stakeholder reassurance | (R1) | Bq $kg^{-1}$ dry<br>Wet /dry ratio | 1-5 targeted at population centres and/or maximum concentration | Annually – 3 yearly | 1 per 3 years - 5 | | No difference |
| | Check/complementary monitoring | (R1)<br>(O1) | Bq $kg^{-1}$ dry<br>Wet /dry ratio | At point of max concentration | Annually – 3 yearly | 1 per 3 years - 1 | | No difference |
| | Assess background (very far field) | (R2) | Bq $kg^{-1}$ dry<br>Bq $m^{-2}$ dry<br>Wet /dry ratio | 1-2 remote locations or done as part of national programme (e.g. on 50km grid across UK ~150 samples every 10 years) | 3 yearly – 10 Yearly | 0 – 2 per 3 years | | No difference |
| | Assess long term trends (indicator) | (R1)<br>(O1) | Bq $kg^{-1}$ dry<br>Bq $m^{-2}$ dry<br>Wet /dry ratio | 1-2<br>Fixed locations -Max concentration, prevailing wind direction | Annually | 1-2 | | No difference |
| | Understand/monitor behaviour of radionuclides in the environment | (R1)<br>(O1) | Bq $kg^{-1}$ dry<br>Bq $m^{-2}$ dry<br>Wet /dry ratio | 1 location - Max concentration. | Annually | 1 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements* | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.14** Grass | Dose Surrogate | (R1) (O1) | Bq $kg^{-1}$ wet Wet/dry ratio | In vicinity of where surrogate food type would have come from e.g. milk, veg Or max concentration | Monthly to Quarterly (during growing season –assumed 8 months) | 2-8 | **Operator** **2-12** **4-60 after incident** **Regulator** **2-20** **+ 150 part of national programme for background every 10 years** | Targeted to known areas of contamination Different radionuclides Seasonal targeting |
| | Provide public & stakeholder reassurance | R1 | Bq $kg^{-1}$ wet Wet/dry ratio | 1-5 targeted at population centres and/or maximum concentration Or emergent issue | Quarterly to annual | 1-20 | | As above |
| | Check/complementary monitoring | (R1) (O1) | Bq $kg^{-1}$ wet Wet/dry ratio | At point of max depostion | Annually – 3 yearly | 1 per 3 years - 1 | | Area of highest contamination |
| | Assess background (very far field) | (R2) | Bq $kg^{-1}$ wet Wet/dry ratio Bq $m^{-2}$ | 1-2 Or done as part of national programme (e.g. on 50km grid across UK ~150 samples every 10 years) | Annual – 10 Yearly | 0 -2 | | No additional requirements |
| | Assess long term trends (indicator) | (R1) O1 | Bq $kg^{-1}$ wet Wet/dry ratio Bq $m^{-2}$ | 1-3 Fixed locations -Max concentration, prevailing wind directions | Quarterly to annual | 1-12 | | Area of highest contamination Annually – 10 years |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | Bq $kg^{-1}$ wet Wet/dry ratio Bq $m^{-2}$ | 1-5 (e.g. max concentration) | Monthly to Quarterly After incident spot samples. | 4-60 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | Bq $kg^{-1}$ wet Wet/dry ratio Bq $m^{-2}$ | 1 location - Max concentration. | Annually | 1 | | Covered by investigation |

* When analysing grass for $^{14}C$ should also include a measurement to determine Bq $kg^{-1}$ carbon.

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.15** Freshwater weed | Assess total representative person dose | R1 | Bq $kg^{-1}$ wet | 1-2 edible species, indicator of edible species or part of food-chain based on habit surveys, maximum concentrations and availability of species | Quarterly-annually | 1-8 | **Operator** **1-8** **4-48 limited nuclides** **Regulator** **1-10** | No difference, where the areas of contamination are. |
| | Assess dose as an operator's performance measure | O1 | Bq $kg^{-1}$ wet | 1-2 edible species, indicator of edible species or part of food-chain based on habit surveys, maximum concentrations and availability of species | Quarterly-annually | 1-8 | | As above |
| | Provide public & stakeholder reassurance | (R1) | Bq $kg^{-1}$ wet | 1-4 edible species, indicator of edible species or part of food-chain based on habit surveys and local concern | Annual Targeted against life cycle of weed | 1-4 | | No difference |
| | Check/complementary monitoring | (R1) (O1) | Bq $kg^{-1}$ wet | 1-2 species and locations where sampled in main programme | Annual – 3 yearly Targeted against life cycle of weed | 1 per 3 years - 2 | | No difference |
| | Assess background (very far field) | R2 | Bq $kg^{-1}$ wet | 1-2 remote locations | Annual - 3 yearly Targeted against life cycle of weed | 0-2 | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | Bq $kg^{-1}$ wet | 1-2 for fixed location / species | Annually | 1-2 | | Unlikely to be best indicator for long term historic contamination concerns |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | Bq $kg^{-1}$ wet | 1-4 cover different species | Monthly-quarterly Limited nuclides | 4-48 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | Bq $kg^{-1}$ wet | 1-2 cover different species | Annually | 1-2 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.16** Wildlife/Game | Assess total representative person dose | R1 | Bq $kg^{-1}$ wet | 0-4 local food types reflecting maximum concentrations and habit surveys | Annually | 0-4 | **Operator** **0-8** **0-24 limited nuclides** **Regulator** **0-10** | Based on habit surveys of where animals grazing contaminated land eg sea to land transfer, sea-washed pastures. |
| | Assess dose as an operator's performance measure | O1 | Bq $kg^{-1}$ wet | 0-4 local food types reflecting maximum concentrations and habit surveys | Annually | 0-4 | | As above |
| | Assess total impact on wildlife (e.g. dose) | R2 | Bq $kg^{-1}$ wet | 0-4 species reflecting maximum concentrations – advanticious finds | Annually (as available) | 0-4 | | As above |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | O2 | Bq $kg^{-1}$ wet | 0-4 species reflecting maximum concentrations – advanticious finds | Annually (as available) | 0-4 | | As above |
| | Provide public & stakeholder reassurance | (R1) | Bq $kg^{-1}$ wet | 0-4 local food types from habit surveys e.g. local farm shops, butchers | Annually | 0-4 | | As above |
| | Check/complementary monitoring | (R1) (O1) | Bq $kg^{-1}$ wet | 0-2 local food types 10% check | Annually – 3 yearly | 0-2 | | No difference |
| | Assess background (very far field) | R3 | Bq $kg^{-1}$ wet | 0-2 remotely sourced food types or done as part of a national programme | Annually – 3 yearly | 0 -2 | | No difference |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O3 | Bq $kg^{-1}$ wet | 0-2 species found on/close to site - advanticious finds | Monthly -Quarterly (as available) Limited indicator radionuclides | 0-24 | | NA |
| | Understand/monitor behaviour of radionuclides in the Food/environment | (R1) (O1) | Bq $kg^{-1}$ wet | 0- 1 local food type reflecting maximum concentration | Annual | 0-1 | | Based on max from knowledge, habit surveys |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.17**<br>Landfill leachates | Assess total representative person dose | R1 | Bq $l^{-1}$<br>Bq $m^{-3}$ | At central collection point prior to disposal e.g. to sewer/tanker | Quarterly – annually | 1-4 | **Operator**<br>**1-4**<br>**4-48 limited nuclides**<br><br>**Regulator**<br>**1-4** | No difference |
| | Assess dose as an operator's performance measure | O1 | Bq $l^{-1}$<br>Bq $m^{-3}$ | At central collection point prior to disposal e.g. to sewer/tanker | Quarterly – annually | 1-4 | | No difference |
| | Provide public & stakeholder reassurance (landfill operatives considered here) | (R1) | Bq $l^{-1}$<br>Bq $m^{-3}$ | At central collection point prior to disposal e.g. to sewer/tanker | Quarterly – annually | 1-4 | | No difference |
| | Check/complementary monitoring | (R1)<br>(O1) | Bq $l^{-1}$<br>Bq $m^{-3}$ | At central collection point prior to disposal e.g. to sewer/tanker | Annually | 1 | | No difference |
| | Assess long term trends (indicator) | (R1)<br>(O1) | Bq $l^{-1}$<br>Bq $m^{-3}$ | At central collection point prior to disposal e.g. to sewer/tanker | Annually | 1 | | No difference |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | Bq $l^{-1}$<br>Bq $m^{-3}$ | 1-4 leachates from affected disposal cells and at central point of collection | Monthly-quarterly<br>Limited indicator radionuclide | 4-48 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.18** Sewage/sludges | Assess total representative person dose | R1 | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 3 sampling points (Raw sewage entering works, treated effluent prior to discharge and final sludge prior to disposal)<br>Also 1-4 locations capturing sludge and effluent throughout process | Quarterly – annually | 4-28 | **Operator**<br>**4-28**<br>**8-24 limited nuclides**<br>**Regulator**<br>**4.3-30** | NA |
| | Assess dose as an operator's performance measure | O1 | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 3 sampling points (Raw sewage entering works, treated effluent prior to discharge and final sludge prior to disposal)<br>Also 1-4 locations capturing sludge and effluent throughout process | Quarterly – annually | 4-28 | | NA |
| | Provide public & stakeholder reassurance | (R1) | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 2 sampling points (Treated effluent prior to discharge and final sludge prior to disposal) | Annually | 2 | | NA |
| | Provide workforce reassurance (Public STW workers) | (O1) | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 1-4 locations capturing sludge and effluent throughout process | Annually | 1-4 | | NA |
| | Check/complementary monitoring | (R1)<br>(O1) | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 3 sampling points (Raw sewage entering works, treated effluent prior to discharge and final sludge prior to disposal) | Annually | 3 | | NA |
| | Assess background (very far field) | R2 | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 1-2 remote sewage works 3 sampling points (Raw sewage entering works, treated effluent prior to discharge and final sludge prior to disposal) | 3 yearly - 10 yearly | 3 per 10 years -6 per 3 years | | NA |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.18 cont.**<br>Sewage/sludges | Assess long term trends (indicator) | (R1)<br>(O1) | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 3 sampling points (Raw sewage entering works, treated effluent prior to discharge and final sludge prior to disposal) | Annually | 3 | | NA |
| | Detect abnormal, fugitive & unauthorised releases (Indicator)<br>For operators being done as part of clearance, regulators may do for public STW | O2 | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 2 sampling points (Raw sewage entering works and final sludge prior to disposal) | Monthly – quarterly<br>Limited indicator radionuclides | 8-24 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1)<br>(O1) | Bq $l^{-1}$<br>Bq $kg^{-1}$<br>Wet/dry ratio<br>Suspended solids content | 2 sampling points (Treated effluent prior to discharge and final sludge prior to disposal) | Quarterly – annually | 2-8 | | NA |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.19**<br>Fish – Marine and freshwater | Assess total representative person dose | R1 | Bq $kg^{-1}$<br>Wet/dry ratio | At least 1 round, 1 flat fish<br>Landed at local ports.<br>Ideally caught within 20km radius of site<br>Local suppliers<br>Farmed fish affected by discharges | quarterly – annually | 2-8+ | **Operator**<br>**2-10+**<br><br>**Regulator**<br>**2-10+**<br>**+ 4-16 part of national programme for background and international obligation** | No difference |
| | Assess dose as an operator's performance measure | O1 | Bq $kg^{-1}$<br>Wet/dry ratio | At least 1 round, 1 flat fish<br>Landed at local ports.<br>Ideally caught within 20km radius of site<br>Local suppliers<br>Farmed fish affected by discharges | quarterly – annually | 2-8+ | | No difference |
| | Assess total impact on wildlife (e.g. dose) | (R1) | Bq $kg^{-1}$<br>Wet/dry ratio | At least 1 pelagic, 1 benthic fish<br>Landed at local ports.<br>Ideally caught within 20km radius of site<br>Local suppliers<br>Farmed fish affected by discharges | Annually | 2 | | No difference |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | (O1) | Bq $kg^{-1}$<br>Wet/dry ratio | At least 1 pelagic, 1 benthic fish<br>Landed at local ports.<br>Ideally caught within 20km radius of site<br>Local suppliers<br>Farmed fish affected by discharges | Annually | 2 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.19 cont.**<br>Fish – Marine and freshwater | Provide public & stakeholder reassurance | (R1) | Bq $kg^{-1}$<br>Wet/dry ratio | At least 1 round, 1 flat fish<br>Landed at local ports.<br>Ideally caught within 20km radius of site<br>Local suppliers<br>Farmed fish affected by discharges | Annually | 2 | | No difference |
| | Check/complementary monitoring | (R1)<br>(O1) | Bq $kg^{-1}$<br>Wet/dry ratio | Either 1 round, 1 flat fish (alternate if poss)<br>Landed at local ports.<br>Ideally caught within 20km radius of site<br>Local suppliers<br>Farmed fish affected by discharges | Annually-3 yearly | 1 per 3 years - 1 | | No difference |
| | Assess background (very far field) | (R2) | Bq $kg^{-1}$<br>Wet/dry ratio | At least 1 round, 1 flat fish remote from site. Or done as part of a national programme | Annually – 3 yearly | 0 -2 | | No difference |
| | Assess long term trends (indicator) | (R1)<br>(O1) | Bq $kg^{-1}$<br>Wet/dry ratio | At least 1 round, 1 flat fish<br>Landed at local ports.<br>Ideally caught within 20km radius of site<br>Local suppliers<br>Farmed fish affected by discharges | Annually | 2 | | No difference |
| | Comply with international obligations | R2 | Bq $kg^{-1}$<br>Wet/dry ratio | Nationally 4 locations range of fish types | Quarterly - Annually | 4-16 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1)<br>(O1) | Bq $kg^{-1}$<br>Wet/dry ratio | At least 1 round, 1 flat fish<br>Landed at local ports.<br>Ideally caught within 20km radius of site<br>Local suppliers<br>Farmed fish affected by discharges | Quarterly-annually | 2-8 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.20** Crustaceans & Molluscs – Marine and freshwater | Assess total representative person dose | R1 | Bq $kg^{-1}$ Wet/dry ratio | 1-4 crustaceans and molluscs (different species where possible) at locations based on habit surveys and maximum concentrations (e.g. known harvesting beds, local suppliers) | Quarterly – annually | 1-16 | **Operator** **2-20** **4-24 limited nuclides** **Regulator** **2-20** **+9-36 part of national programme for background and international obligation** | No difference |
| | Assess dose as an operator's performance measure | O1 | Bq $kg^{-1}$ Wet/dry ratio | 1-4 crustaceans and molluscs (different species where possible) at locations based on habit surveys and maximum concentrations (e.g. known harvesting beds, local suppliers) | Quarterly – annually | 1-16 | | No difference |
| | Assess total impact on wildlife (e.g. dose) | (R1) | Bq $kg^{-1}$ Wet/dry ratio | 1-4 crustaceans and molluscs (different species where possible) at locations based on maximum concentrations | Annually | 1-4 | | No difference |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | (O1) | Bq $kg^{-1}$ Wet/dry ratio | 1-4 crustaceans and molluscs (different species where possible) at locations based on maximum concentrations | Annually | 1-4 | | No difference |
| | Provide public & stakeholder reassurance | (R1) | Bq $kg^{-1}$ Wet/dry ratio | 1-4 crustaceans and molluscs from locations based on habit surveys, max concentration and local concern. Both directions from pipeline. | Annually | 1-4 | | No difference, except both directions from discharge point no longer relevant. |
| | Check/complementary monitoring | (R1) (O1) | Bq $kg^{-1}$ Wet/dry ratio | 1-2 crustaceans and molluscs from same locations as main programme (rotate locations around discharge point) | Annually – 3 yearly | 1 per 3 years - 2 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.20 cont.** Crustaceans & Molluscs – Marine and freshwater | Assess background (very far field) | (R2) | Bq $kg^{-1}$ Wet/dry ratio | 1-2 crustaceans and molluscs remote from site. Or done as part of a national programme. | Annually -3 yearly | 0 -2 | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | Bq $kg^{-1}$ Wet/dry ratio | 1-2 crustaceans and molluscs max concentration both directions from pipeline. | Annually | 1-2 | | No difference |
| | Comply with international obligations | R2 | Bq $kg^{-1}$ Wet/dry ratio | Nationally 9 locations range of molluscs and crustaceans | Quarterly - Annually | 9-36 | | NA |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) Seaweed might be a better indicator | O3 | Bq $kg^{-1}$ Wet/dry ratio | 1-2 crustaceans and molluscs max concentration both directions from pipeline. | Monthly -Quarterly Limited indicator radionuclides | 4-24 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | Bq $kg^{-1}$ Wet/dry ratio | 1-2 crustaceans and molluscs max concentration both directions from pipeline. | Annually | 1-2 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.21**<br>Sediment – Estuary/coastal freshwater | Assess total representative person dose | (R1) | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-4 locations based on habit surveys and maximum concentrations | Quarterly –Annually | 1-16 | **Operator**<br>**1-40**<br>**4-72 limited nuclides**<br><br>**Regulator**<br>**1-80** | No difference |
| | Assess dose as an operator's performance measure | O1 | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-10 at locations based on habit surveys and maximum concentrations | Quarterly – Annually | 1-40 | | No difference |
| | Assess total impact on wildlife (e.g. dose) | (R1) | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-4 targeted to sensitive wildlife and max concentrations | Annually | 1-4 | | No difference |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | (O1) | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-10 targeted to sensitive wildlife and max concentrations | Annually | 1-10 | | No difference |
| | Provide public & stakeholder reassurance | R1 | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-20 Targeting non-critical habits further afield. Local concern. | Quarterly – annually | 1-80 | | No difference |
| | Check/complementary monitoring | (R1)<br>(O1) | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-10 locations with range of concentrations | 6 monthly – annually | 1-20 | | No difference |
| | Assess background (very far field) | R2 | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-2 remote locations or done as part of a national programme | Annually – 3 yearly | 0-2 | | No difference |
| | Assess long term trends (indicator) | (R1)<br>(O1) | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-3 locations, Max concentration, both directions from site | Annually | 1-3 | | No difference |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-6 locations<br>Close to pipeline to modelled area of maximum impact. Both directions from site | Monthly- Quarterly<br>Limited indicator radionuclides | 4-72 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1)<br>(O1) | Bq kg$^{-1}$ dry<br>Wet/dry ratio | 1-3 locations, Max concentration, both directions from site | Annually | 1-3 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.22** Seawater collected from shore | Assess total impact on wildlife (e.g. dose) | (R1) | Bq $l^{-1}$ filtrate<br>Bq $kg^{-1}$ particulate<br>Suspended solids content $Bqm^{-3}$ | 1-2 based on maximum concentrations and locations of sensitive wildlife | Annually | 1-2 | **<u>Operator</u>**<br>**1-2**<br>**4-48 limited nuclides**<br>**<u>Regulator</u>**<br>**1-4**<br>**+12-24 part of national programme for background and international obligation** | No difference |
| | Assess impact on wildlife as an operator's performance measure (e.g. dose) | O1 | Bq $l^{-1}$ filtrate<br>Bq $kg^{-1}$ particulate<br>Suspended solids content $Bqm^{-3}$ | 1-2 based on maximum concentrations and locations of sensitive wildlife | Annually | 1-2 | | No difference |
| | Provide public & stakeholder reassurance | R1 | Bq $l^{-1}$ filtrate<br>Bq $kg^{-1}$ particulate<br>Suspended solids content $Bqm^{-3}$ | 1-4<br>Locations based on non-critical habits, local concerns, close to pipeline and to modelled area of maximum impact. Both directions from site | Annually | 1-4 | | No difference |
| | Check/complementary monitoring | (R1)<br>(O1) | Bq $l^{-1}$ filtrate<br>Bq $kg^{-1}$ particulate<br>Suspended solids content $Bqm^{-3}$ | 1 - maximum concentration | Annually | 1 | | No difference |
| | Assess background (very far field) | (R2) | Bq $l^{-1}$ filtrate<br>Bq $kg^{-1}$ particulate<br>Suspended solids content $Bqm^{-3}$ | 1-2 remote locations or done as part of a national programme | 3 yearly – 10 yearly | 0-2 per 3 years | | No difference |
| | Assess long term trends (indicator) | (R1)<br>(O1) | Bq $l^{-1}$ filtrate<br>Bq $kg^{-1}$ particulate<br>Suspended solids content $Bqm^{-3}$ | 1 - maximum concentration | Annually | 1 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.22 cont.** Seawater collected from shore | Comply with international obligations | R2 | Bq $l^{-1}$ filtrate Bq $kg^{-1}$ particulate Suspended solids content $Bqm^{-3}$ | 1-2 in whole UK as part of national programme | Monthly – check | 12-24 | | NA |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) **Scale from pipes** | O2 | Bq $l^{-1}$ filtrate Bq $kg^{-1}$ particulate Suspended solids content $Bqm^{-3}$ | 1-4 locations Close to pipeline to modelled area of maximum impact. Both directions from site | Monthly – quarterly Limited indicator radionuclides | 4-48 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | Bq $l^{-1}$ filtrate Bq $kg^{-1}$ particulate Suspended solids content $Bqm^{-3}$ | 1 - maximum concentration | Annually | 1 | | No difference |

| Sample / Monitoring type | Objectives | | Data Requirements | Location | Frequency | Number Range / Year | Total No. of Samples / Year | Differences for Historical Releases |
|---|---|---|---|---|---|---|---|---|
| **3.23** Seaweed | Assess total representative person dose | R1 | Bq kg$^{-1}$ wet | 1-4 where seaweed consumed or used as fertiliser, based on habit surveys and availability of species | Quarterly-annually | 1-16 | **Operator** **1-16** **4-48 limited nuclides** **Regulator** **1-16** **+1-10 part of national programme for background** | No difference, where the areas of contamination are. |
| | Assess dose as an operator's performance measure | O1 | Bq kg$^{-1}$ wet | 1-4 where seaweed consumed or used as fertiliser, based on habit surveys and availability of species | Quarterly-annually | 1-16 | | As above |
| | Provide public & stakeholder reassurance | (R1) | Bq kg$^{-1}$ wet | 1-10 where seaweed consumed or used as fertiliser, based on habit surveys | Annual Targeted against life cycle of seaweed | 1-10 | | No difference |
| | Check/complementary monitoring | (R1) (O1) | Bq kg$^{-1}$ wet | 10% i.e. 1 location | Annual – 3 yearly Targeted against life cycle of seaweed | 1 per 3 years - 1 | | No difference |
| | Assess background (very far field) | R2 | Bq kg$^{-1}$ wet | 1-10 for UK 1-2 remote locations or done as part of a national programme | Annual - 3 yearly Targeted against life cycle of seaweed | 0-10 | | No difference |
| | Assess long term trends (indicator) | (R1) (O1) | Bq kg$^{-1}$ wet | 1-4 cover different species | Quarterly-annually | 1-16 | | Unlikely to be best indicator for long term historic contamination concerns |
| | Comply with International obligations | (R2) | Bq kg$^{-1}$ wet | 1-10 in whole UK as part of a national programme | Annual Targeted against life cycle of seaweed | 0-10 | | No difference |
| | Detect abnormal, fugitive & unauthorised releases (Indicator) | O2 | Bq kg$^{-1}$ wet | 1-4 cover different species | Monthly-quarterly Limited nuclides | 4-48 | | NA |
| | Understand/monitor behaviour of radionuclides in the environment | (R1) (O1) | Bq kg$^{-1}$ wet | 1-4 cover different species | Quarterly-annually | 1-16 | | No difference |

## Table 4 – Guidance on how to monitor and sample

Check monitoring would be undertaken in the same way as the monitoring being checked.

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.1a**<br>Dose rate monitoring – (Terrestrial) (fluctuating dose rates and secure location) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public, stakeholder and workforce Reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Detect abnormal, fugitive and unauthorised releases*** | • Select passive dose rate monitor (e.g. TLD, film badge).<br>• Instrument should meet defined performance criteria.<br>• Ensure secure location.<br>• Establish cosmic background.<br>• Results reported as $\mu Gyh^{-1}$ air kerma (state whether corrected for cosmic). | • Locate at height of 1 – 1.5 m in a secure location.<br>• Locate such that shielding from source of exposure is minimised (e.g. away from walls, trees, hedges and roads).<br>• 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.<br>• 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. | - |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.1b**<br>Dose rate monitoring (Terrestrial) (non-fluctuating dose rates or non-secure location) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public, stakeholder and workforce Reassurance***<br>• ***Assess background***<br>• ***Assess long term trends*** | • Select instrument to take spot measurement (e.g. Mini 6-80, energy compensated NaI(Tl) detector).<br>• Instrument should meet defined performance criteria, to include [Ref 6]:<br>- Inherent background dose rate <0.015μGyh$^{-1}$ $^{226}$Ra γ<br>- Cosmic ray response <0.07μGyh$^{-1}$ $^{226}$Ra γ<br>- Air kerma based response ± 30 % of the response to $^{137}$Cs γ radiation over the energy range 80 keV to 1.25 MeV<br>- Adequate polar response<br>- Precision<br>• Establish cosmic & intrinsic background.<br>• Ensure instrument is calibrated regularly (e.g. annually).<br>• Ensure instrument is functioning before and after monitoring survey period (or weekly).<br>• Correct measurements for cosmic & intrinsic detector background.<br>• Results reported as μGyh$^{-1}$ air kerma. | • Take measurement at height of 1 m.<br>• Locate such that shielding from source of exposure is minimised (e.g. away from walls, trees, hedges and roads).<br>• Take reading over sufficient time period to achieve sufficient statistical confidence at the defined minimum dose rate measurement limit.<br>• 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).<br>• Note that where geology is changing rapidly it may be difficult to choose a reference background dose rate for comparison | - |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.2**<br>Dose rate monitoring (Inter-tidal/ marine) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Assess total impact on wildlife (dose) and as a performance measure***<br>• **Provide *public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Identify and note sediment type and weather conditions.<br>• Select instrument to take spot measurement (e.g. Mini 6-80, energy compensated NaI(Tl) detector ).<br>• Instrument should meet defined performance criteria, to include [Ref 6]:<br>- Inherent background dose rate $<0.015\mu Gyh^{-1}$ $^{226}Ra$ $\gamma$<br>- Cosmic ray response $<0.07\mu Gyh^{-1}$ $^{226}Ra$ $\gamma$<br>- Air kerma based response ± 30 % of the response to $^{137}Cs$ $\gamma$ radiation over the energy range 80 keV to 1.25 MeV<br>- Adequate polar response Precision<br>• Establish cosmic & intrinsic background.<br>• Ensure instrument is calibrated regularly (e.g. annually).<br>• Ensure instrument is functioning before and after monitoring survey period (or weekly).<br>• Correct measurements for cosmic & intrinsic detector background.<br>• Results reported as $\mu Gyh^{-1}$ over sediment type (including natural background). | • Take measurement at height of 1 m.<br>• Operator should stand at least 10 m away from the detector to prevent effects of shielding.<br>• Take reading over sufficient time period to achieve sufficient statistical confidence at the defined minimum dose rate measurement limit.<br>• 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).<br>• Note that where geology is changing rapidly it may be difficult to choose a reference background dose rate for comparison. | - |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.2**<br>Dose rate monitoring (Inter-tidal/ marine) (cont) | • ***Assess total representative person dose and dose as a performance measure*** | • Identify and note sediment type and weather conditions.<br>• Select instrument to take spot measurements (e.g. Berthold 122)<br>• Instrument should meet defined performance criteria, to include:<br>- Detection efficiency / sensitivity capability<br>- Precision<br>- Energy response that matches the quantity of interest<br>• Ensure instrument is calibrated regularly (e.g. annually).<br>• Ensure instrument is functioning before and after monitoring survey period (or weekly).<br>• Results reported as $\mu Gyh^{-1}$ over sediment type (including natural background). | • The height at which to take the measurement should be appropriate to the habit being assessed (e.g. 15cm for seated anglers).<br>• Take appropriate number of readings across the surface, to be representative of the item being monitored, with shield on ($\gamma$ only) and without shield ($\beta$ and $\gamma$).<br>• Take reading over sufficient time period to achieve defined dose rate measurement limit (using integrating function of instrument). | - |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.3a**<br>Contamination monitoring (Inter-tidal / marine) – Strandline and small particles and objects (***by foot***) | • ***Provide public and stakeholder reassurance***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Monitoring by foot where this is more cost effective than monitoring by vehicle.<br>• Identify and note point in the tidal cycle. Allow for tide times to ensure access.<br>• Identify and note the weather conditions.<br>• Select instrument to take measurements (e.g. probe with Geiger-Muller detector)<br>• Instrument should meet defined performance criteria, (to enable a active items as defined to be detected) to include:<br>- Detection efficiency / sensitivity capability<br>- Precision<br>- Detector should be chosen to maximise the ability to detect the potential contaminant taking account of the local background<br>- Response time<br>• Ensure instrument is calibrated regularly (e.g. annually).<br>• Ensure instrument is functioning before and after monitoring survey period (or weekly).<br>• Results reported as counts/s.<br>• Also $\mu Svh^{-1}$ from the active items 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.<br>• 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. < 0.5m/s). Looking to detect an increase in counts.<br>• Procedures should be defined for what action to take if a active items is found. These will need to address health & safety requirements, responsibility for custody and detailed analytical requirements.<br>• 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.<br>• Record general count rate range for the defined transect that has been surveyed. | - |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.3b**<br>Contamination monitoring (Inter-tidal / marine) – Strandline and small particles and objects (***by vehicle***) | • ***Provide public and stakeholder reassurance***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Monitoring by vehicle where this is more cost effective than monitoring by foot.<br>• Identify and note point in the tidal cycle. Allow for tide times to ensure access.<br>• Identify and note the weather conditions.<br>• Select instrument to take measurements (e.g. NaI (Tl) detectors, vehicle/detectors)<br>• Instrument should meet defined performance criteria, (to enable an active item as defined to be detected) to include:<br>- Detection efficiency / sensitivity capability<br>- Precision<br>- Detector should be chosen to maximise the ability to detect the potential contaminant taking account of the local background<br>- Response time<br>• Ensure instrument is calibrated regularly (e.g. annually).<br>• Ensure instrument is functioning before and after monitoring survey period (or weekly).<br>• Results reported as $\mu Svh^{-1}$ from the active items 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.<br>• Travel the area using sweeps, at intervals to meet defined detection criteria.<br>• Procedures should be defined for what action to take if an active item is found. These will need to address health & safety requirements, responsibility for custody and detailed analytical requirements.<br>• 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.<br>• Record general count rate range for the defined transect that has been surveyed. | - |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.3c** Contamination monitoring (Inter-tidal / marine) – areas where active items are prone to accumulate. | • ***Provide public and stakeholder reassurance*** | • See Nairn conference proceedings [Ref 13] | - | - |
| **4.3d** Contamination monitoring of objects (ropes, nets, lobster pots) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance*** | • Select instrument to take spot measurements (e.g. Berthold 122)<br>• Instrument should meet defined performance criteria, to include:<br>- Detection efficiency / sensitivity capability<br>- Precision<br>- Energy response that matches the quantity of interest<br>- Appropriate calibration factor developed<br>• Ensure instrument is calibrated regularly (e.g. annually).<br>• Ensure instrument is functioning before and after monitoring survey period (or weekly).<br>• Results reported as $\mu Gyh^{-1}$. | • Take measurement at just above the material being monitored, ensuring that window membrane is not punctured.<br>• For ropes and nets, monitor in the manner used by fishermen.<br>• Take appropriate number of readings across the surface, to be representative of the item being monitored, with shield on ($\gamma$ only) and without shield ($\beta$ and $\gamma$).<br>• Take reading over sufficient time period to achieve defined dose rate measurement limit (using integrating function of instrument). | - |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.4**<br>High/Medium Volume Air Sampling (HVAS / MVAS) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases.***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Ensure secure site and power supply.<br>• Ensure noise is minimised.<br>• HVAS/MVAS needs to collect total particulate (i.e. not specific size range) – This is cautious for the objectives.<br>• Air flow to be measured with defined uncertainty (best practice instrument maintain flowrate automatically) – calibration will be required.<br>• Filters should trap >95% of particle size >0.3 µm AMAD [Ref 7].<br>• Mass of particulate collected to be measured (e.g. filters weighed before and after collection).<br>• Results reported as Bq $m^{-3}$. | • Cross-contamination to be avoided (e.g. sealed in polythene bags, take blank filters to field).<br>• Ensure filters can be identified (e.g. uniquely label filters).<br>• Sample for a period to ensure that defined detection limits can be achieved and avoid filter blinding (2 weeks is typical). | - |
| See also Table 5 for more information on ambient air monitoring for radioactivity. | | | | |
| **4.5**<br>Passive Shades | • ***Provide public and stakeholder reassurance***<br>• ***Assess long term trends***<br>• ***Detect abnormal, fugitive and unauthorised releases.***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Collect total particulate on suitable shade material<br>• Results reported as Bq/shade | • Cross-contamination to be avoided (e.g. sealed in polythene bags, take blank shades to field).<br>• Ensure shades can be identified (e.g. uniquely label shades).<br>• Sample for a period to ensure that defined detection limits can be achieved, but short enough to allow for detection of abnormal events. | |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.6**<br>Total deposition (wet and dry) | • ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases.***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Collect in a deposition collector (e.g. rain gauge).<br>• Minimise adsorption of radionuclides to container (e.g. pre-soak containers and use carrier solutions).<br>• Minimise growth of algae (e.g. use brown collection bottle).<br>• Report results as Bq $l^{-1}$ or $Bqm^{-2}/s$. | • Record area of collection funnel and duration of time sample collected.<br>• 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 $4^{o}C$).<br>• Filter samples through a 0.45µm membrane and analyse filtrate and residue if the monitoring objective requires information on the partitioning between dissolved and particulate phases (e.g. particulate deposition).<br>• Ensure representative sub-sample is taken for analysis (e.g. shake liquid samples).<br>• Bulk or concentrate samples (e.g. through ion exchange or evaporation) to achieve detection limits, if required. |
| **4.7a**<br>Water -Surface freshwater (e.g. rivers, streams, lakes) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases.***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Determine appropriate sample container dependent upon radionuclide(s) to be sampled.<br>• Report results as Bq $l^{-1}$. | • Rinse collection apparatus and container with sample.<br>• Collect representative sample.<br>• Store the sample to prevent deterioration in transit to the lab (e.g. 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).<br>• Filter samples through a 0.45µm membrane and analyse filtrate and residue if the monitoring objective requires information on the partitioning between dissolved and particulate phases.<br>• Ensure representative sub-sample is taken for analysis (e.g. shake water sample).<br>• Concentrate sample if needed (e.g. through ion exchange or evaporation).<br>• Preserve with nitric acid for long storage (analysis dependant). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.7b**<br>Water -Drinking water<br>(tap water) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Determine appropriate sample container dependent upon radionuclide(s) to be sampled.<br>• Decide upon whether you want mains tap water or the water from within the household pipework.<br>• Record site location of sample.<br>• Follow radon specific protocol if measuring for radon [Ref 12].<br>• Report results as Bq $l^{-1}$. | • Rinse collection apparatus and container with sample.<br>• 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).<br>• Collect water sample directly into the container.<br>• Minimise radionuclide adsorption to container walls by adding a carrier or preservative to water as appropriate (dependent upon the radionuclide).<br>• Store the sample to prevent deterioration in transit to the lab (e.g. cool, dark conditions). | • Minimise growth of algae and avoid degradation of sample (e.g. by keeping sample cool and in the dark during storage).<br>• Do not filter sample.<br>• Concentrate sample if needed (e.g. through ion exchange or evaporation). |
| **4.7c**<br>Water - Drinking water (wells or groundwater - assumed to be local consumers direct from groundwater via borehole or spring) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Detailed guidance on collection of groundwater samples is provided in References 1 – 5.<br>• Determine appropriate sample container dependent upon radionuclide(s) to be sampled.<br>• If used, confirm borehole is suitable for sampling and representative of the water consumed.<br>• Record site location of sample.<br>• Follow radon specific protocol if measuring for radon [Ref 12].<br>• Report results as Bq $l^{-1}$. | • Identify geochemical strata (water origin).<br>• Select collection apparatus (e.g. bailer or pump) – use pump only if content < 5% solid. Suction pumps are only recommended for depths of <8m. A submersible pump is required for deeper boreholes.<br>• Purge borehole (e.g. 3 borehole volumes or purge until water characterisation parameters such as pH, temperature, and dissolved oxygen stabilise)<br>• Rinse collection apparatus and container with sample.<br>• Collect representative sample.<br>• Minimise radionuclide adsorption to container walls by adding a carrier or preservative to water as appropriate (dependent upon the radionuclide).<br>• Store the sample to prevent deterioration in transit to the lab (e.g. cool, dark conditions). | • Keep sample cool (away from heat sources) and in the dark during storage.<br>• Do not filter sample.<br>• Concentrate sample if needed (e.g. through ion exchange or evaporation). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
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| **4.8**<br>Milk and dairy products | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Two methods of preparation either the analysis of the raw edible fraction (e.g. milk collected directly from the farm) or via culinary preparation (in the case of milk this might mean sampling processed butter, milk etc).<br>• Report results as Bq $l^{-1}$. 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).<br>• 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 etc.<br>• Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample).<br>• Add carrier or preservative to milk as appropriate depending upon the radionuclide.<br>• Store the sample to prevent deterioration in transit to the lab (e.g. store in air tight containers, cool box). | • Select a representative sub-sample for analysis (eg shake milk sample).<br>• Concentrate sample if needed (e.g. evaporation, ion-exchange, freeze drying). |
| **4.9**<br>Meat & meat products including wild or game foods | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Prepare the raw edible fraction for analysis (e.g. from a mature animal that would be sold commercially. Culinary preparation may need to be taken into account).<br>• Approach outlined is for longer lived radionuclides that will still exist by the time the food product is available for human consumption.<br>• Consider the need for local sampling versus retail sampling for national averages.<br>• Report results as Bq $kg^{-1}$ (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).<br>• 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).<br>• Select sample(s) of muscle, liver and kidney (where there is a market for offal e.g. from farmed animals) as these cover the main sites of radionuclide accumulation and are all consumed in significant quantities.<br>• Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample).<br>• 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).<br>• Prepare samples to provide edible fraction (may require culinary preparation depending upon the objective).<br>• 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).<br>• Record dry/fresh ratio.<br>• 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). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
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| **4.10**<br>Poultry, eggs | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • 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.<br>• Approach outlined is for longer lived radionuclides that will still exist by the time the food product is available for human consumption.<br>• Consider the need for local sampling versus retail sampling for national averages<br>• Report results as Bq $kg^{-1}$ (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 (e.g. the thigh or breast for the bird to ensure select the edible fraction).<br>• Select a representative sample.<br>• Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample).<br>• 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).<br>• Prepare samples to provide edible fraction (may require culinary preparation depending upon the objective).<br>• Dry sample to constant weight (e.g. air dry, 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).<br>• Record dry/fresh ratio.<br>• Select a representative sub-sample for analysis (e.g. by homogenising dry sample in mill or blender; blending/whisking/stirring honey/eggs; or mincing fresh sample. Cone and quarter if appropriate). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
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| **4.11**<br>Fruit & Vegetables including wild foods such as:<br><br>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 | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Prepare the raw edible fraction (e.g. mature fruit/vegetable as may be sold commercially) for analysis. Culinary preparation may need to be taken into account.<br>• Approach outlined is for longer lived radionuclides that will still exist by the time the food product is available for human consumption.<br>• Consider the need for local sampling versus retail sampling for national averages.<br>• Report results as Bq $kg^{-1}$ (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided. | • Identify sample type.<br>• Collect sample and remove any extraneous material.<br>• Select a representative sample of the source material. When sampling in the field consider the location and size of area to be sampled (e.g. 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 etc to sample. For wild foods consider number of plants sampled (e.g. for blackberries and other hedgerow species, sample from along a 10m length of hedge).<br>• Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample).<br>• Store the sample to prevent deterioration in transit to the lab (e.g. store in air tight containers). | • Wash in water to remove soil (vegetables) and chemicals (fruit).<br>• Store samples in lab to prevent deterioration (e.g. chill at about $4^{o}$C or freeze)<br>• Prepare samples to provide edible fraction (may require culinary preparation depending upon the objective).<br>• Dry sample to constant weight (e.g. air dry oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides.<br>• Record dry/fresh ratio.<br>• Select a representative sub-sample for analysis (e.g. by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
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| **4.12**<br>Cereal | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Prepare the raw edible fraction (e.g. mature grain) for analysis. Culinary preparation may need to be taken into account (in the case of cereal this might mean sampling bread).<br>• Approach outlined is for longer lived radionuclides that will still exist by the time the food product is available for human consumption.<br>• 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.<br>• Consider the need for local sampling versus retail sampling for national averages.<br>• Report results as Bq $kg^{-1}$ (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided. | • Identify cereal type.<br>• Sample the material at an appropriate time (e.g. as mature grain straight from the field or as grain that has been harvested).<br>• Select a representative sample of the source material. When sampling in the field consider the location and size of area to be sampled (e.g. 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 etc to sample.<br>• Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample).<br>• 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)<br>• Prepare samples to provide edible fraction (may require culinary preparation depending upon the objective).<br>• Dry sample to constant weight (e.g. air dry, oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides.<br>• Record dry/fresh ratio.<br>• Select a representative sub-sample for analysis (e.g. by homogenising dry sampled in mill or blender or blending fresh samples, Cone and quarter if appropriate). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.13a**<br>Soil | • ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Comply with international obligations*** | • Samples should be collected from undisturbed permanent pasture<br>• The area may be fenced off to protect the collection site.<br>• Samples of soil in the root zone should be collected to achieve these objectives (typically 2-5cm).<br>• 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.<br>• Report results as Bq $kg^{-1}$ (dry weight) | • Obtain a reasonably representative sample over a scale of up to 5-10 m. This may be achieved by collecting 5 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.<br>• Remove surface litter and overlying vegetation.<br>• 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).<br>• 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).<br>• Record dry/wet ratio.<br>• Remove gravel component by sieving to <2mm and discarding >2mm fraction.<br>• Ensure representative sub-sample is taken for analysis (e.g. by grinding and coning and quartering). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.13b**<br>Soil | • ***Assess long term trends***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Samples should be collected from undisturbed permanent pasture<br>• The area may be fenced off to protect the collection site.<br>• Samples will need to be sufficiently deep to achieve monitoring objectives. A typical practical depth is 15 cm.<br>• Report results as Bq $kg^{-1}$ (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 5 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.<br>• Remove surface litter and overlying vegetation.<br>• 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.<br>• Record the area from of the sample (e.g. area of the core).<br>• 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 soils. 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.<br>• Sub-sample from centre of each core slice to reduce smearing. | • As above |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.14**<br>Grass/ Herbage | • ***Dose surrogate***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations*** *(instead of milk)*<br>• ***Detect abnormal, fugitive and unauthorised releases.***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Area may be fenced off to prevent removal of grass and unwanted additions (e.g. animal droppings, fertiliser). Also enables growth since last sample to be collected.<br>• Samples should be collected at same location as soil samples if the objective is to validate dispersion, deposition and transfer modelling.<br>• Report results as Bq $kg^{-1}$ (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 5 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.<br>• Trim sample approx 10mm above soil surface with shears (or similar), taking care not to collect any soil and excluding non-herbage (i.e. woody) material.<br>• Store sample to prevent deterioration (e.g. airtight container). | • Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4$^{o}$C or freeze).<br>• 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).<br>• Record dry/wet ratio.<br>• Ensure representative sub-sample is taken for analysis (e.g. use blender). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.15**<br>Freshwater weed | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Detect abnormal, fugitive and unauthorised releases.***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Consider seasonal (annual) cycle on sampling strategy.<br>• Selection of recent growth for analysis will provide a better indicator of recent discharges than analysis of a whole plant which will lead to an indicator of integrated discharges over a few years.<br>• Report results as Bq $kg^{-1}$ (fresh weight) | • Correctly identify single species (including hybrids) as determined to meet objective. May need to be a food species (e.g. water cress).<br>• Collect and trim recent growth from plant or parts used for food (as applicable) according to local practice.<br>• Wash in water to remove particulates.<br>• Store the sample to prevent deterioration in transit to the lab (e.g. cool, dark conditions, cool box). | • Store samples at laboratory to prevent degradation and loss of volatiles, if appropriate (e.g. chill at about 4°C or freeze).<br>• Dry sample to constant weight (e.g. air dry, oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides.<br>• Record dry/fresh ratio.<br>• Select a representative sub-sample for analysis (e.g. by homogenising dry sampled in mill or blender or blending fresh samples, Cone and quarter if appropriate). |
| **4.16**<br>Wildlife<br>(All species but not domesticated species such as cattle, sheep etc) | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Report results as Bq $kg^{-1}$ (fresh weight). If results are reported as dry weight then the fresh:dry weight ratio should be provided.<br><br>For some objectives there is likely to be ad hoc monitoring or based on sample availability rather than routine targeted sampling. | • Select species for required sampling.<br>• 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.<br>• Record the provenance of the sample to ensure traceability of the sample back to the field (links to representative nature of the sample).<br>• Store the sample to prevent deterioration in transit to the lab (e.g. store in air tight container, cool box). | • Store samples in lab to prevent deterioration (e.g. chill at about 4°C or freeze)<br>• Prepare samples as whole (including entrails) OR prepare specific portion of sample (e.g. feathers).<br>• Record weights of parts required for analysis and for discarded parts.<br>• 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).<br>• Record dry/fresh ratio.<br>• 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). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.17**<br>Landfill leachates | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess long term trends***<br>• ***Detect abnormal, fugitive and unauthorised releases*** | • Detailed guidance on collection of samples from boreholes is provided in References 1 – 5.<br>• Report results as Bq $l^{-1}$ (for dissolved and particulate phases) and kg/l of particulate (if appropriate). | • Determine sample collection depth based on monitoring requirements.<br>• Select collection apparatus (e.g. bailer or pump) – use pump only if content < 5% solid. Suction pumps are only recommended for depths of <8m. A submersible pump is required for deeper boreholes.<br>• Purge borehole (3 borehole volumes).<br>• Rinse collection apparatus and container with sample.<br>• Collect representative sample.<br>• Store the sample to prevent deterioration in transit to the lab (e.g. cool, dark conditions). | • Store samples at laboratory to minimise growth of algae and avoid degradation of sample (e.g. chill at about $4^{o}$C or freeze in the dark).<br>• Filter samples through a 0.45µm 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).<br>• Ensure representative sub-sample is taken for analysis (e.g. shake liquid samples). |
| **4.18**<br>Sewage/sludges | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public, stakeholder and workforce reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Report results as Bq $l^{-1}$ or Bq $kg^{-1}$ (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).<br>• Dry sample to constant weight and preventing 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).<br>• Record dry/wet ratio.<br>• Ensure representative sub-sample is taken for analysis (e.g. shake liquid samples). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.19**<br>Fish - Marine and freshwater | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Select species to meet monitoring objective (e.g. benthic versus pelagic, stage of growth, availability in the fishing ground).<br>• Report results as Bq $kg^{-1}$ (fresh weight). | • Correctly identify species caught by net or line.<br>• Store the sample to prevent deterioration in transit to the lab (e.g. 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).<br>• Prepare the raw edible fraction for analysis. Culinary preparation may need to be taken into account.<br>• Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides.<br>• Record dry/wet ratio.<br>• Select a representative sub-sample for analysis (e.g. by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate). |
| **4.20**<br>Crustaceans & Molluscs – Marine and freshwater | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Select species to meet monitoring objective.<br>• Report results as Bq $kg^{-1}$ (fresh weight). | • Correctly identify species.<br>• Collect by hand sampling or using pots or digging as appropriate for species.<br>• Do not depurate.<br>• Store the sample to prevent deterioration in transit to the lab (e.g. 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).<br>• Prepare the raw edible fraction for analysis. Culinary preparation may need to be taken into account.<br>• Dry sample to constant weight (e.g. oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides.<br>• Record dry/wet ratio.<br>• Select a representative sub-sample for analysis (e.g. by homogenising dry sample in mill or blending fresh samples. Cone and quarter if appropriate). |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.21**<br>Sediments - Estuary/coastal and freshwater | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Allow for tide times to ensure access.<br>• Ensure depositional environment.<br>• Report results as Bq $kg^{-1}$ (dry weight).<br>• For freshwater samples take from exposed river bed or banks of river (if regularly inundated). Use hand-held detectors to guide sampling. | • Take samples from predominant sediment type.<br>• Obtain a reasonably representative sample over a scale of up to 5-10 m. This may be achieved by collecting 5 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. For freshwater samples this may be achieved by selecting sampling positions from five points along the exposed river bed or bank at distance of 1m apart. The samples may be bulked.<br>• 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).<br>• 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).<br>• Record dry/wet ratio.<br>• Remove gravel component by sieving to <2mm and discarding >2mm fraction.<br>• Ensure representative sub-sample is taken for analysis (e.g. by grinding and coning and quartering).<br>• For some objectives may need to normalise or report factors which can influence concentrations (e.g. grain size (loss on ignition at 450°C a good proxy*), total organic carbon) or restrict grain size (e.g. <250µm). [Refs 8 & 11] |

| Sample type | Objective | General | Sampling/Monitoring | Sample preparation |
|---|---|---|---|---|
| **4.22**<br>Seawater (collected from shore) | • ***Assess total impact on wildlife (dose) and as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess Background***<br>• ***Assess long term trends***<br>• ***Comply with international obligations***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Beach collection of seawater samples.<br>• Minimise adsorption of radionuclides to container (e.g. pre-soak containers and use carrier solutions).<br>• Report results as Bq $l^{-1}$. | • Allow for tide times to ensure access (for beach collection).<br>• Rinse collection apparatus and container with sample.<br>• Collect water (use water submersible pump for large volume samples or bucket/carboy for small volume samples).<br>• Continuous automatic sampling maybe required.<br>• Store the sample to prevent deterioration in transit to the lab (e.g. 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).<br>• Filter samples through a 0.45µm membrane and analyse filtrate and residue if the monitoring objective requires information on the partitioning between dissolved and particulate phases.<br>• Ensure representative sub-sample is taken for analysis (e.g. shake water sample).<br>• Concentrate sample if needed (e.g. through ion exchange or evaporation).<br>• Preserve with nitric acid for long storage (analysis dependant). |
| **4.23**<br>Seaweed | • ***Assess total representative person dose and dose as a performance measure***<br>• ***Provide public and stakeholder reassurance***<br>• ***Assess background***<br>• ***Assess long term trends***<br>• ***Detect abnormal, fugitive and unauthorised releases***<br>• ***Understand/monitor behaviour of radionuclides in the environment*** | • Consider seasonal (annual) cycle on sampling strategy.<br>• 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.<br>• Report results as Bq $kg^{-1}$ (fresh weight) | • Allow for tide times to ensure access (for beach collection).<br>• Correctly identify single species (including hybrids) as determined to meet objective. May need to be a food species.<br>• Collect and trim recent growth from fronds or parts used for food or compost (as applicable) according to local practice.<br>• Note presence of fruiting bodies which may affect results, due to changes in plant physiology.<br>• Wash in water to remove particulate and epiphytes (unless to represent use as compost).<br>• Store the sample to prevent deterioration in transit to the lab (e.g. 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).<br>• Dry sample to constant weight (e.g. air dry, oven dry 40 – 105ºC, freeze-dry), but analyse fresh for volatile radionuclides.<br>• Record dry/fresh ratio.<br>• Select a representative sub-sample for analysis (e.g. by homogenising dry sampled in mill or blender or blending fresh samples, Cone and quarter if appropriate). |

## Table 5 – Guidance ambient air monitoring for radioactivity

| Aspect of monitoring | Performance criteria | Guidance |
|---|---|---|
| Monitoring locations | Characterise air concentrations at locations of highest air concentration (breathing zone), exposed population groups and background locations | Minimum of three locations monitored around a nuclear site at location of modelled highest ground-level air concentration, exposed population group with highest air concentration and one background location. |
| Locating sampler | Representative monitoring location over a distance of about 100m at breathing height. | Samplers situated away from major obstructions such as trees, buildings etc.<br>Air inlet at breathing height, at least 1.5m from the immediate ground level. Ideally the inlet should be less than 4m from ground level |
| Data capture | At least 95% of time | Measures to improve monitoring reliability, include:<br>• Brushless motors<br>• Reliable electrical supply suitably protected to prevent accidental damage<br>• Secure location for sampler to protect against accidental or deliberate damage. |
| Detection limit | As an example, the detection limit for Be-7 would be around 0.06 mBq $m^{-3}$ based on a sample flow rate of 1.2 $m^3$/min and an analytical detection limit of 3.2 Bq per filter set | A sampling period of about 1 month with a sampler flow rate of about 1-2 $m^3$/min should achieve this detection limit. Bulking of samples over 3 months may be acceptable to achieve detection limits. Filter material should be selected to help ensure most suitable analytical method is used to achieve detection limits. Polycarbonate filter papers can be fully ashed and digested or quartz fibre filters can be leached to enable a solution to be analysed. This is likely to achieve a better detection limit than compressing filters and counting directly by gamma-spectrometry. |
| Particle size | No size selective inlet. | Most commercial filter papers should be near 100% efficient and it is more important to consider the analytical characteristics of the papers. The samplers used were standard design high volume samplers that are understood to have a 50% sampling efficiency for particles with mean aerodynamic diameters between 10 µm and 18 µm at average wind speeds (the difference is due to the relative orientation of the sampler roof to the source). The system should be near 100% efficient at particle diameters <5 µm. |
| Volumetric flow | Measured with an uncertainty of +/- 7% | Flow-rate sensor should be calibrated against a calibrated flow orifice or transfer standard. Calibrations should be undertaken when High Volume Air Samplers are first purchased, after every motor or brush change, anytime the flow sensor is replaced or adjusted, anytime a one-point audit check deviates more than 7% from the custom calibration or at least every six months.<br>Calibration of the standard orifice should be undertaken on an annual basis using an ISO17025 accredited laboratory. |
| Cross-contamination | Cross-contamination avoided | Sample handling protocols should be defined to protect sample filter papers (e.g. using gloves and transport containment). Blank filters should follow same sample |

| **Aspect of monitoring** | **Performance criteria** | **Guidance** |
|---|---|---|
| | | handling procedures and then be analysed. |
| Health and safety | Noise | Insofar as the application of Statutory Instrument 2005 no 14643 Health and Safety The Control of Noise at Work Regulations 2005 the period of operation at the sampler is limited to typically less than 30 minutes (say during calibrations) so the assessment must be based on the workers additive dose over the working day and week so the complete work pattern must be taken into account. The dose contribution from the sampler needs to be measured as the working range and this will vary from depending on motor type and speed. The most significant noise risk is on sampler start up if the flow settings are fully open during installation if drilling is required as part of the process. |
| | Electrical installation to BS7671 | Equipment should not be electrically modified unless performed by a qualified electrician. Field technicians can undertake basic installations limited to wiring of plugs provided their employer has suitably trained them. |
| | PAT testing following HSE guidance note 107 | A suitably trained technician can carry this out. Training would be provided by either a nominated member of staff that holds a recognised qualification or by a recognised body such as the City and Guilds PAT testing course. |
| Quality assurance | Verification of the chain of custody so that the lifecycle of any measurement can be documented. | The use of a chain of custody to tie in all other records is imperative. |
| | Assessment of the reported data | Essentially a ‘reality’ check on the levels found. |
| | QA accreditation | The analytical lab should carry UKAS accreditation for the determinands and demonstrate compliance with ISO17025. |

# Appendix 1 – Interpretation of IAEA Safety Standard on environmental and source monitoring

The International Atomic Energy Agency (IAEA) has published a safety standard on environmental and source monitoring [Ref 1]. It provides guidance on what should be monitored and at what frequency for releases to air and water. However, it does not give guidance on how many different types of samples (e.g. types of vegetables) should be collected or how many locations they should be collected from.

An interpretation of this IAEA Safety Standard is provided in this appendix on the total number of annual samples which should be collected by making minimal, reasonable and maximum assumptions about number of types of samples and locations. This interpretation is shown in Tables A1.1 and A1.2 and displayed in Figures A1.1 and A1.2. This interpretation of the total number of samples required has been used as a framework for defining the guidance in the rest of this document.

## Table A1.1 Interpretation of IAEA Safety Standard for environmental monitoring associated with releases to air

| Monitoring type | IAEA guidance | Minimal interpretation of IAEA guidance | | Reasonable interpretation of IAEA guidance | | Maximal interpretation of IAEA guidance | |
|---|---|---|---|---|---|---|---|
| | | Description | Samples per year | Description | Samples per year | Description | Samples per year |
| Dose rate monitoring | Continuously | Continuously at maximum air concentration. On-line instrumental monitoring. | Every 10-15 s at 1 location | Continuously at maximum air concentration (1), nearby population centres (3) and background locations (2). On-line instrumental monitoring | Every 10-15 s at 6 locations | Continuously around site (5), at maximum air concentration (1), nearby habitation (5) and background locations (3). On-line instrumental monitoring | Every 10-15 s at 14 locations |
| Air | Continuously, monthly measurement | Continuously at maximum air concentration, monthly measurement | 12 | Continuously, monthly measurement at maximum air concentration (1), nearby population centres (3) and background locations (2) | 72 | Continuously, monthly measurement around site (4), at maximum air concentration (1), nearby habitation (4) and background locations (3). | 144 |
| Rain / total deposition | Continuously, monthly measurement | Continuously at maximum air concentration | 12 | Continuously at maximum air concentration (1), nearby population centres (3) and background locations (2) | 72 | Continuously, monthly measurement around site (4), at maximum air concentration (1), nearby habitation (4) and background locations (3). | 144 |
| Soil | Once per year | Once per year at maximum air concentration | 1 | Once per year at maximum air concentration (1), nearby population centres/farms (3) and background locations (2) | 6 | Once per year, around site (4), at maximum air concentration (1), nearby population centres/farms (4) and background locations (3) | 12 |
| Leafy vegetables | Every month during growing season | Every month during growing season (3 months) (1 type) at maximum air concentration | 3 | Every month during growing season (3 months) (2 types) at maximum air concentration (1) and other location (1) | 12 | Every month during growing season (3 months) (3 types) at maximum air concentration (1) and other locations (2) | 27 |
| Other vegetables and fruit | Selected samples at harvest | Selected samples (2 types) at harvest (once per year) at maximum air concentration | 2 | Selected samples (3 types) at harvest (once per year) at maximum air concentration (1) and other locations (2) | 9 | Selected samples (5 types) at harvest (once per year) at maximum air concentration (1) and other locations (3) | 20 |

## Table A1.1 Continued

| Monitoring type | IAEA guidance | Minimal interpretation of IAEA guidance | | Reasonable interpretation of IAEA guidance | | Maximal interpretation of IAEA guidance | |
|---|---|---|---|---|---|---|---|
| | | Description | Samples per year | Description | Samples per year | Description | Samples per year |
| Grain (cereal) | Selected samples at harvest | Selected samples (2 type) at harvest (once per year) at maximum air concentration | 2 | Selected samples (2 types) at harvest (once per year) at maximum air concentration (1) and other locations (2) | 6 | Selected samples (2 types) at harvest (once per year) at maximum air concentration (1) and other locations (2) | 6 |
| Milk | Every month when cows are on the pasture | Every month when cows are on the pasture (8 months) at maximum air concentration | 8 | Every month when cows are on the pasture (8 months) at maximum air concentration (1), nearby farms (3) and background locations (2) | 48 | Every month when cows are on the pasture (8 months) at maximum air concentration (1), nearby farms (5) and background locations (3) | 72 |
| Meat | Selected samples, twice per year | Selected samples (2 types), twice per year at maximum air concentration | 4 | Selected samples (3 types), twice per year at maximum air concentration (1) and other locations (2) | 18 | Selected samples (5 types), twice per year at maximum air concentration (1) and other locations (3) | 40 |
| Drinking water and groundwater | Twice per year | Twice per year at one location | 2 | Twice per year at a few locations (3) | 6 | Twice per year at some locations (5) | 10 |
| Grass | Every month when cows are on the pasture | Every month when cows are on the pasture (8 months) at maximum air concentration | 8 | Every month when cows are on the pasture (8 months) at maximum air concentration (1), nearby population centres/farms (3) and background locations (2) | 48 | Every month when cows are on the pasture (8 months), around site (4), at maximum air concentration (1), nearby population centres/farms (4) and background locations (3) | 96 |
| Lichens, mosses, mushrooms | Selected samples, once per year | Some selected samples (2 types), once per year at maximum air concentration | 2 | Some selected samples (3 types), once per year at maximum air concentration (1) and other locations (2) | 9 | Some selected samples (5 types), once per year at maximum air concentration (1) and other locations (3) | 20 |

## Table A1.2 Interpretation of IAEA Safety Standard for environmental monitoring associated with releases to water

| Monitoring type | IAEA guidance | Minimal interpretation of IAEA guidance | | Reasonable interpretation of IAEA guidance | | Maximal interpretation of IAEA guidance | |
|---|---|---|---|---|---|---|---|
| | | **Description** | **Samples per year** | **Description** | **Samples per year** | **Description** | **Samples per year** |
| Surface water (freshwater and marine) | Continuous sampling, monthly measurement | Continuous sampling, monthly measurement at one location | 12 | Continuous sampling, monthly measurement at a few locations (3) | 36 | Continuous sampling, monthly measurement at some locations (5) | 60 |
| Sediment | Once per year | Once per year at one location | 1 | Once per year at a few locations (3) | 3 | 4 times per year at some locations (5). [Greater frequency of monitoring might be more appropriate for significant discharges]. | 20 |
| Fish | Selected samples, once per year | Selected samples (2 types), once per year at one location | 2 | Selected samples (3 types), once per year at a few locations (3) | 9 | Selected samples (3 types), once per year at some locations (5) | 15 |
| Shellfish (e.g. mollusc, crustacean) | Selected samples, twice per year | Selected samples (2 types), once per year at one location | 2 | Selected samples (3 types), once per year at a few locations (3) | 9 | Selected samples (3 types), once per year at some locations (5) | 15 |
| Seaweed, marine sponges | Selected samples, twice per year | Selected samples (2 types), twice per year at one location | 4 | Selected samples (3 types), twice per year at a few locations (3) | 18 | Selected samples (3 types), twice per year at some locations (5) | 30 |
| Benthic animals (e.g. mollusc, crustacean) | Selected samples, twice per year | Selected samples (2 types), twice per year at one location | 4 | Selected samples (3 types), twice per year at a few locations (3) | 18 | Selected samples (3 types), twice per year at some locations (5) | 30 |

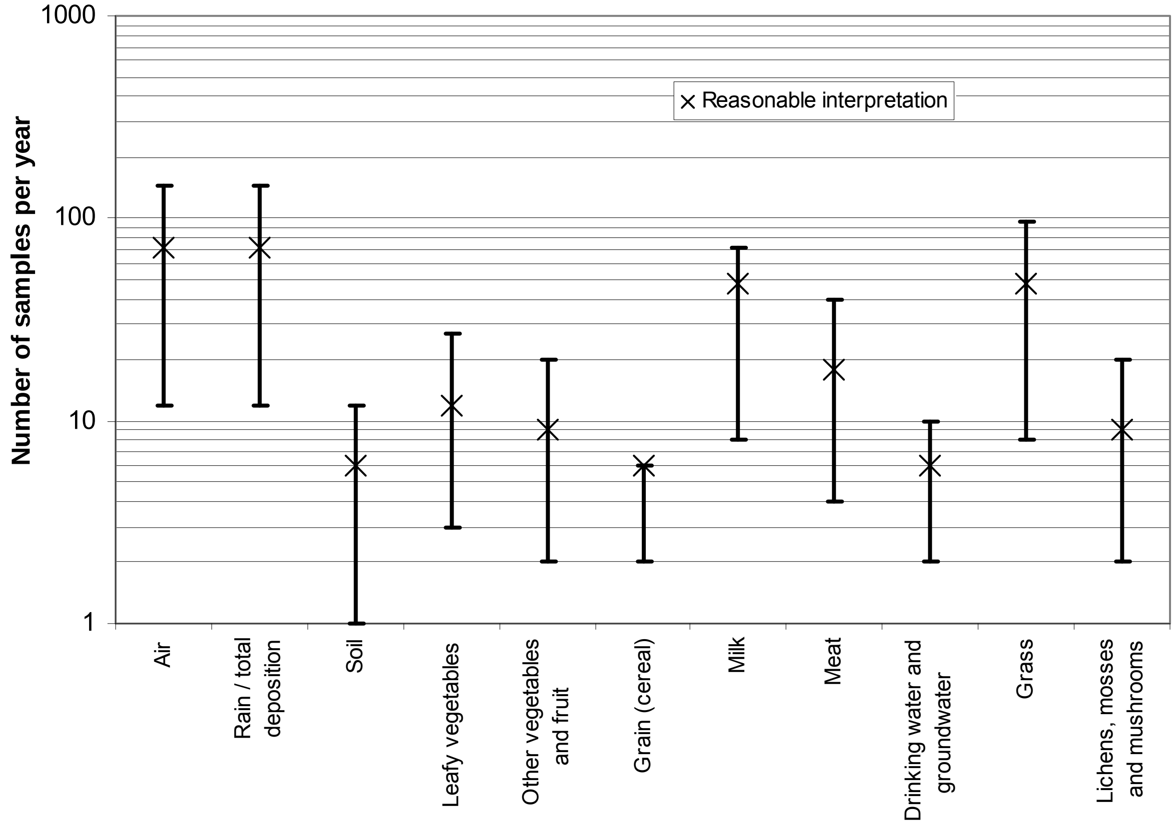


**Figure A1.1 Interpretation of IAEA Guidance for number of samples – Releases to air**

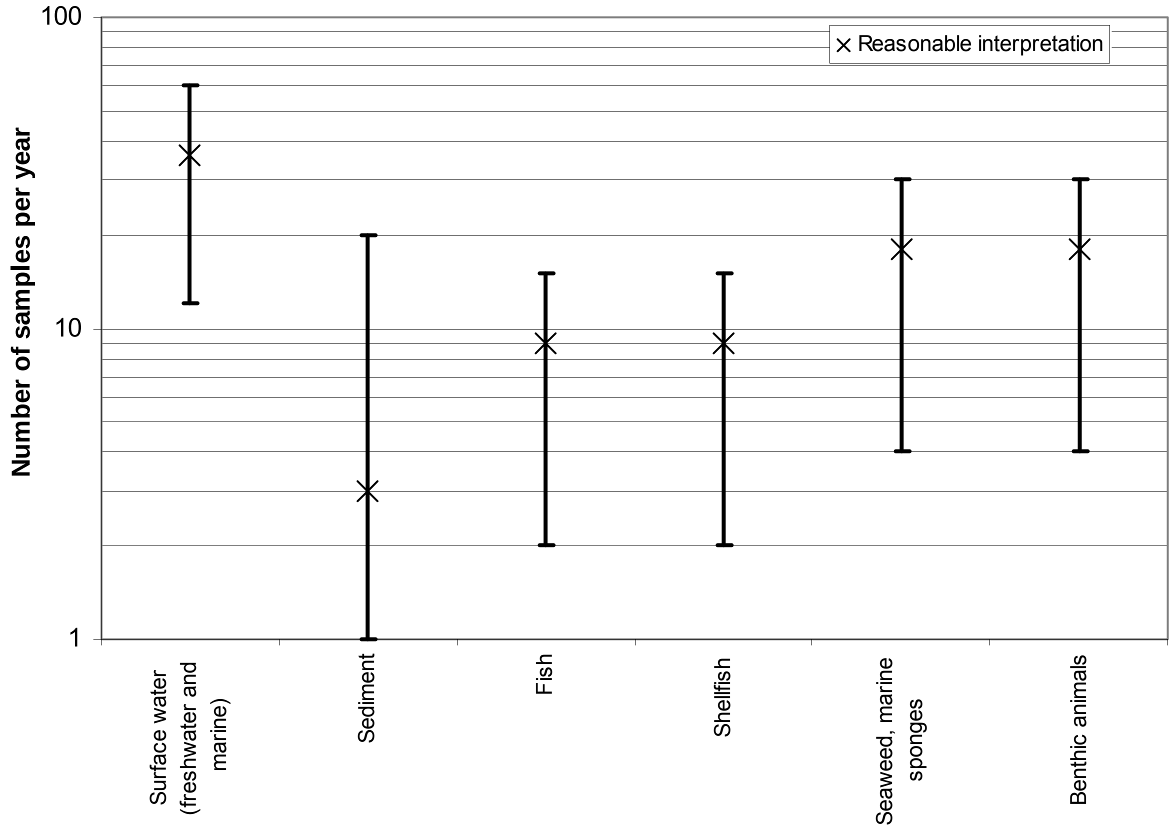


**Figure A1.2 Interpretation of IAEA Guidance for number of samples – Releases to water**