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Uncertainty matrix applicable to the ERICA Tool

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ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management) will provide an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of contaminants emitting ionising radiation, with emphasis on biota and ecosystems. The project started in March 2004 and is to end by February 2007.

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Table of Content

Executive Summary

This report extends the text published in Section 3.4 of the ERICA deliverable D8 - Considerations for applying the ERICA Integrated Approach (Zinger *et al.*, 2007).

Practical options for dealing with data gaps and uncertainties

The most appropriate practical approaches for dealing with uncertainties and gaps in data will depend upon the assessment context and on the form of the type of uncertainty concerned – whether it primarily arises from incomplete knowledge (which can be addressed by additional research) or from natural variability (which cannot be reduced by additional research).

In order to assist the assessor, key practical options available for dealing with knowledge gaps and uncertainties, when applying the ERICA Tool, have been identified within matrix. The types of issues, options exist and their strengths and weakness are outlined. This matrix is provided in the Annex 2 of D8, and some of the main features are outlined below for ease of reference.

The options matrix

This matrix is intended to provide the user of the tool with options for dealing with uncertainties – its focus is thus on the application of the ERICA tool rather than on the uncertainties inherent in the development of the tool and the underlying models. The structure of the matrix is as follows:

Table 1: Structure of the options matrix.

Issue	Description	Types of uncertainty	Options	Strengths	Weaknesses
		U or V or DG*			

***Uncertainty (U):** arises from imprecision due to lack of information, expert judgement and/or measurement errors and could be reduced with increased knowledge and/or experimentation. **Variability (V):** otherwise referred to as natural variability and results from heterogeneity. Variability is inherent and cannot be eliminated in general. **Data Gap (DG).**

The types of issue for which decisions may be required have been grouped into the various steps involved in conducting an assessment:

- source characterisation, including source monitoring, radionuclide selection and discharge routes;
- ecosystem analysis, involving both biota and environmental characterisation;
- environmental transfer, which incorporates the transfer of radionuclides from environmental media to organisms and the subsequent assessment of internal and external dose rates;
- effects analysis; and,
- interpretation and evaluation.

Each issue has been classified in terms of the general type of uncertainty it represents. However, it is recognised that the type of uncertainty associated with an issue may vary depending on both the context of the assessment and the tier being applied.

The matrix information is intended to help the assessor to identify the practical options for coping with an incomplete data set – arising from uncertainty or variability – and to make choices on the basis strengths and weaknesses associated with them (including issues such as stakeholder acceptance, resource implications and the extent of expert consultation likely to be required). The extent to which different

options are applicable or feasible will be determined by the primary type and characteristics of uncertainty concerned. Some general considerations are outlined below.

- Measurement or data uncertainties – can be reduced by further measurement to a certain extent, although errors in measurement and uncertainties arising from natural variability will remain following additional measurements.
- Scenario uncertainties – or incomplete information about the situation to be assessed – may be reduced in some cases (for short-term retrospective assessments for example additional measurements may provide additional information). However, these types of uncertainty are generally accounted for by making alternative assumptions about the situation, e.g. maximising assumptions (as implied by the semi-quantitative treatment defined by the scenario sub dimension of the level of uncertainty defined by Walker and van der Sluijs).
- Conceptual uncertainties – arising from the conceptualisation of natural processes into simplified functions, e.g. the consideration of complex dynamic environmental processes as transfer coefficients between simplified environmental compartments. This type of uncertainty is fundamental to the process or situation being modelled and it is difficult to consider in a purely numerical way. It may correspond to uncertainties in the context of expert judgement – and relate to knowledge uncertainties, recognised ignorance.
- Model uncertainties – relate to uncertainties in the numerical implementation of the conceptual model – the uncertainties in the model may be studied (and to some extent reduced) by numerical means, for example by undertaking verification and validation exercises. The applicability of model parameters may be improved by additional measurements – but variability uncertainty will remain.
- Parameter (or data) uncertainty – is often difficult to distinguish from model uncertainty. Such uncertainties may be reduced by undertaking focused experimental work but uncertainties related to natural variability will remain.

The options referred to in Appendix 1 of this Annex 2 provide practical alternatives for deriving specific parameters, in the absence of a full dataset. Some general features are summarised below.

Table 2: Summary of practical options for dealing with data gaps and uncertainties.

Options	Strengths	Weaknesses
Ignore process or source of uncertainty of concern	Easy to apply	Provides no information about the likely importance of process or uncertainty. Likely to be difficult to justify to stakeholder groups
Maximising assumptions about the relevant parameter	Easy to apply – provides an upper estimate of the likely influence of parameter or uncertainty	Could lead to significant overestimation and unnecessary concerns
Additional literature research with application of single value parameters	Confidence in results of additional literature search.	Rather resource-intensive and requires specialist knowledge to make use of primary literature information. Does not necessarily reduce uncertainties arising from variability/site-specific issues or allow uncertainties to be quantitatively assessed.

Options	Strengths	Weaknesses
Site-specific or relevant experimentation – to derive single value (site specific) parameters	Greater confidence that parameters are applicable to the site being considered – should reduce uncertainties primarily to intrinsic local variability.	Very resource-intensive; high level of expert input required to design and perform site-specific survey to provide representative input. Single-value parameter derivation does not provide for a sensitivity or uncertainty analysis.
Additional literature research to develop distribution of relevant parameters (for inclusion in sensitivity and uncertainty analysis)	Greater confidence that uncertainties are included as an intrinsic part of the assessment; provides basis for sensitivity analysis which could provide basis for focusing effort for more detailed uncertainty.	Resource-intensive and specialist input needed to undertake search and develop necessary distributions.
Application of expert elicitation techniques to derive a parameter distribution	When well structured – the approach can add to buy-in and increase confidence in results	Expert planning required to ensure consistency of results.
Site specific or relevant experimentation to derive distributions of relevant parameters (for inclusion in sensitivity and uncertainty analysis)	The most comprehensive treatment of parameter uncertainty possible – may add to confidence in results	Very resource intensive, the site-specific research, interpretation of experimental results and the application and interpretation of uncertainty analysis results will require detailed expert input.

Example of use of the uncertainty matrix

The uncertainty matrix described above also provides a practical framework for recording the uncertainty-related decisions. A simplified version is given as an example in Table 3.

Table 3: Example of use of the uncertainty matrix.

Location		Type of uncertainty			Nature of uncertainty		
		Statistical	**Scenario - range**	**Ignorance**	**Knowledge-related**	**Inherent variability**	**Quality of knowledge base**
Assessment Tool							
Model Parameters	CRs	Site specific concentration ratios (e.g. in Tier 3)			Conceptual and model uncertainties related to the use of simple equilibrium factors to model complex dynamic process - apply to any use of CRs	Appropriate sampling and analysis	Good - specific to situation being considered
		Generic data for Cs-137 and Sr-90 distribution data and statistics available			As above	Site-specific applicability unknown	Much of CR database related to human modelling requirements
			Choice of CRs based on expert judgement and extrapolation methods, e.g. on trace or chemically similar elements		As above	Significant - related to site-specific variation and variations in radionuclide/organism characteristics	Depends on radionuclide and organisms involved - may vary between moderate and poor
				For many other radionuclides, or maximising assumptions			Poor knowledge base

Location		Type of uncertainty			Nature of uncertainty		
		Statistical	**Scenario - range**	**Ignorance**	**Knowledge-related**	**Inherent variability**	**Quality of knowledge base**
	Kds	Site-specific data			Model and conceptual uncertainties related to use of distribution coefficient apply to use of site-specific and generic values	High degree of variability for different sites due to selinity, redox, sediment load etc.	Good knowledge base if site-specific analysis appropriate
			Single-value ranges of Kd values generally available (e.g. IAEA)			See above	Moderate-poor depending on radionuclide
	DCC		Organism-specific geometry applied (Tier 3)		Applicability of whole body coeficients due to heterogeneity in dose distribution for some radionuclides		Best available
			Application of generic geometry and DCC values			Significant - due to variations in size and shape of organism and target-source configurations	Applicability will depend on the organism concerned
	Weighting factors	For gamma and beta radiation	For alpha - due to internal incorporation			Variation in biological effectiveness of different radiation types in inducing different biological endpoints	Knowledge base varies depending on organism and biological effect type

Location		Type of uncertainty			Nature of uncertainty		
		Statistical	**Scenario - range**	**Ignorance**	**Knowledge-related**	**Inherent variability**	**Quality of knowledge base**
	Occupancy factors		Ranges of values based on observations for generic species	Applicability to specific species (and specific life stages) unknown		Significant variations with climate and organism	Generally unspecific database of information
Model inputs	Radionuclides	Discharge and monitoring information available for some sites and radionuclides			The chemical form of the radionuclide may not be known in detail	Temporal and spatial variability	Well known - scientific judgements
	Activities		Given incomplete information on radionuclides present - assumptions and ranges necessary		Exact nature of radionuclides may not be known		
	Reference organism		semi-quantitative judgements on reference organisms applicability to species of concern			Natural variability difficult to accommodate in simple assessment	Varies from good/moderate to poor - depending on information available for given species and organism.
Outputs	Effects analysis	For some effects and organisms			Related to type of effect - individual or population; use of laboratory information to the field;	Natural variation in sensitivity of different organisms and species; analysis of experimental protocols	Good for some species and endpoints - poor for others

Location		Type of uncertainty			Nature of uncertainty		
		Statistical	**Scenario - range**	**Ignorance**	**Knowledge-related**	**Inherent variability**	**Quality of knowledge base**
			For some effects and organisms derived from information on analogue organisms		Information available for sub-set of organisms	See above	Poor for many organisms
	Derivation and application of dose rate or concentration benchmarks	For species where distribution information exisits - possible to use species sensitivity distributions to derive 'no effects' levels			Multiple stressor or inter-organisms events may affect sensitivity that are not taken into account	Natural variability in sensitivity (see 'effects analysis')	Subjective valuation related to the percentiles used for benchmarks
				Where effects information is sparce - uncertainties may be taken into account by application of safety factors		See above	Poor scientific basis for decisions

Appendix 1: Uncertainty matrix applicable to the ERICA Tool

*** Three types of uncertainties: (U) uncertainty/ (V) variability / (DG) data gap**

Issue	Description	Type*	Options	Strengths	Weaknesses
Source characterisation					
Source monitoring					
Discontinuous emissions monitoring	Emissions may be variable, which is not reflected in emissions monitoring programme	U/V	**Tier 1**: Assume maximum activity concentration detected or modelled/predicted to apply for the entire period of assessment	Conservative approach not requiring additional resources	This typically conservative approach may result in assessments exceeding action levels in circumstances where a more realistic assessment would suggest there was no need for concern
			Tier 2: Undertake monitoring of discharge or source of activity in the environment to gather more specific information	More accurate assessment of levels of activity entering or present in the environment on which to base assessment	Resource-intensive survey work likely to require expert consultation
			Tier 2: Undertake modelling study based on understanding of general discharge behaviour to determine likely concentration ranges within environmental compartments	Not resource intensive and allows informed judgement of likely consequences of variation in emissions	Not as robust as conducting discharge monitoring
			Tier 3: Undertake more detailed assessment of the variability of discharges with time and undertake assessment that takes account of temporal variability (e.g. based on more appropriate averaging but continuing to apply equilibrium assumptions if appropriate)	Reasonable approach where discontinuity does not significantly influence exposure or effects analysis (e.g. in relation to the life-time or occupancy of the biota group concerned)	Resource-intensive and requiring expert consultation

Issue	Description	Type*	Options	Strengths	Weaknesses
Transient conditions and temporal variability	Transient, non-equilibrium conditions may influence the activity present and transfers and uptakes (e.g. from unplanned release, or short-term exposure during particular season that is particularly relevant to the assessment of biota effects)	V/U	**Tiers 2 and 3**: Consider the appropriate temporal averaging appropriate for the biota concerned and undertake appropriate measurements	Confident that temporal averaging will reflect organisms of concern, leading to more accurate exposure and effects analysis	Resource-intensive and requiring expert consultation
			Tier 3: Take account of the transient conditions by applying dynamic environmental transfer modelling external to the ERICA tool	More accurate assessment of levels of activity in biota of concern leading to more accurate effects analysis	Resource-intensive. Data on exposure and effects are not always sufficient to support dynamic modelling. Requires consultation Data may be unavailable in the literature to enable dynamic models for the particular situation to be developed/applied
Environmental activity concentrations (measured or modelled) do not take account of spatial variability	Sampling locations may not be representative of environmental contamination	U	**Tier 1**: Assume maximum activity concentration detected or modelled/predicted to apply	Simple screening approach. May be sufficient for low concentration sources	Conservative approach likely to lead concentration 'limiting' values being exceeded unnecessarily
			Tier 2 may be necessary to interpolate concentration at site of interest using dispersion assumptions.	Easy to apply (models form part of ERICA tool)	Uncertainties and variability in activity concentrations will remain that are not assessed in this process

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3: Survey of spatial distribution and extent of biota and specific allowance in assessment. Assess dose based on frequency of occurrence within the area of interest	Accurate assessment of exposure and effects that is more representative of the location of interest; uncertainty and sensitivity analysis allows importance of spatial variability to be studied	Resource-intensive and requiring expert consultation
			Tier 3: Enter values beyond a discharge point that provide a more representative value for calculation of population relevant exposures.	Accurate assessment of exposure and effects that is more representative of the location of interest.	Resource-intensive and requiring expert consultation
There may be contributions from more than one source (e.g. contamination from other source or from past discharge)	Radionuclides may be deposited in the environment from more than one source; consideration of a single source (e.g. on the basis of current discharges alone) may lead to impacts being underestimated	U	**Tier 2**: Evaluate the existing dose rate arising from all sources based on information available in literature (e.g. on the activity concentrations existing in the area of interest)	Limited additional resource implications, provides confidence that additional sources taken into account	The information available in the literature will be generic in nature and not necessarily applicable to the specific area of interest. This approach does not provide quantitative evaluation of uncertainties.
			Tier 2: Undertake assessment for each site and combine results	Complete assessment with the same level of consideration for each	More resource-intensive than consideration of a single site, there may be problems involved in combination of results
			Tiers 2 and 3: Undertake environmental sampling programme that takes account of contributions from all sources in the area of interest	Confidence that this approach will reflect the specific nature of the multiple sources existing in the area	Sampling, design and interpretation of results would require expert consultation, does not take quantitative account of uncertainties

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3: Undertake site-specific assessment and uncertainty analysis	Confidence that this approach will reflect the specific nature of the multiple sources existing in the area, and allow for uncertainties in a quantitative manner (assuming other parameters are dealt with in a proportionate manner).	Resource intensive and requiring expert consultation
Unknown source term	Contamination may result from diffuse releases or from historic activities	DG/U	**Tier 1**: Apply conservative assumptions on the presence and activity concentrations of radionuclides at the site of interest	Expert judgement required. Subject to error	
			Tier 2: Review available information on past activities / possible sources of contamination to identify possible radionuclides and activity concentrations	Could result in an inaccurate / incomplete assessment. May be resource intensive if modelling required to determine activity concentrations	
			Tier 3: conduct environmental monitoring to determine radionuclides present and activity concentrations in environmental media	confidence that assessment will be based on site-specific data	Resource intensive.
Radionuclide					
Radionuclide may not exist in ERICA database	An assessment of impacts of a radionuclide not present in the ERICA database may be required	DG	**Tier 1**: Go to **Tier 2**	Approach does not require additional resource	Significant uncertainties will exist in the application of this information
			Tiers 2 and 3: Use ERICA tool to access information from ICRP 38 on relevant radionuclide transformations, energy and intensity of emissions for the radionuclide of interest and use this information (together with geometry information for biota) to assess dose rates. CR data will also be required.	Easy to apply (models form part of ERICA tool)	Likely to be incomplete assessment (external dose only); expert analysis will be necessary

Issue	Description	Type*	Options	Strengths	Weaknesses
Speciation of radionuclide	Chemical form of radionuclide may affect transfer, uptake, metabolism and internal distribution - the form and effect on transfer may be unknown	U/DG	**Tier 1** concentrations will be based on generic assumptions that encompass a range of different physico-chemical forms where possible for a radionuclide.	Easily applied approach	Data may lead to overestimation (although there is also the potential for underestimation if the radionuclide is present in an unusual form)
			For **Tier 2** gather information (e.g. from literature, operator information) on the chemical form to influence choice of parameters of concern, e.g. CR and Kd.	Not significantly more work than using default information	More likely to be representative of the nuclides under consideration
			Tier 3: Take account of the range of parameter values due to speciation in defining uncertainty distributions	This approach allows the sensitivity of results to the range of input parameters to be studied (to focus further work, e.g. measurement programmes)	The definition of distributions may require consultation with an expert
			For **Tier 3**, the form of radionuclides determined by measurement and choice of appropriate parameter distributions to form basis of uncertainty analysis	The assessment will be more situation-specific	It may be resource-intensive to obtain spatial/temporally representative information
Radionuclides in source or discharge unknown	Discharges or monitoring results may be reported as total alpha/beta and radionuclide contributions are unknown	DG	**Tier 1** - assess using worst case substitution (e.g., assume 100% alpha is Pu-239, 100% beta is Cs-137), taking account of site knowledge on likely radionuclide emissions)	This provides an easy scoping assessment	This approach may lead to 'limiting concentrations' being exceeded unnecessarily. May require expert consultation.
			Tier 2: Obtain more information on the radionuclides (e.g. from past site experience)	This approach is likely to be more accurate than application of default conservative assumptions while not being resource-intensive	The approach may not be accurate if there has been a significant change in release or source characteristics

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3 - Conduct emissions and/or environmental measurements to determine radionuclides present	Measurement data for the environmental medium of concern will provide the most accurate assessment of the radionuclides present (and their quantities)	Resource-intensive. It may be difficult to obtain measurement results in environmental materials that exceed detection limits. Sampling programme design and performance would require consultation with an expert
Activity concentrations present in the environment unknown	Activity concentrations in the environment are required for an assessment to be conducted - often this information is interpolated from information on releases to the environment	DG	**Tier 1**: Assume maximum expected concentration in water or soil (from previous experience, authorisation assessments or other relevant information)	Simple screening approach. May be sufficient for low concentration sources	May be over-conservative leading to 'limiting concentrations' being exceeded unnecessarily. Inherent uncertainty in the assessment may reduce stakeholder confidence
			Tier 1: If discharge rates are known, apply IAEA SRS19 model to estimate environmental concentrations.	Easy to apply	Model is not site-specific so may result in degree of uncertainty
			Tier 1: Estimate the activity concentration at location(s) of interest from discharge information, using dispersion models included in ERICA Assessment tool	This is a useful approach where there is some but incomplete information available (e.g. activity concentrations at point of release but not at the location of biota of interest)	The dispersion assumptions used in this approach do not take account of site-specific topography or surface water conditions.
			Tier 2: Estimate the activity concentration at location(s) of interest from discharge information, using dispersion models included in ERICA Assessment tool	This is a useful approach where there is some but incomplete information available (e.g. activity concentrations at point of release but not at the location of biota of interest)	The dispersion assumptions used in this approach do not take account of site-specific topography or surface water conditions.

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Undertake environmental monitoring at the location of the biota of interest	This is potentially the most accurate approach on which to base dose rate or risk assessments	Relatively resource-intensive and it may be difficult to obtain measurement results in environmental materials that exceed detection limits. Sampling programme design would require consultation with an expert.
			Tiers 2 and 3: Conduct robust dispersion modelling taking account of site specific conditions	Provides potentially more accurate assessment of dispersion	Can be resource intensive where models have not been calibrated for the characteristics of the area in question
	Monitoring results are below limit of detection (LoD)	U	**Tiers 2 and 3**: Where all results are consistently below the limit of detection, assume radionuclide is not present.	This approach is easy to apply	This approach may lead false negative results
			Tiers 2 and 3: Where a proportion of results are below the limit of detection, assume concentration is half the value of the LoD	This approach reflects the expected statistical distribution of results around the LoD, and allows all radionuclides with positive measurement results to be taken into account	This result may result in false positive results
Radionuclides give rise to progeny of potential importance	It is necessary to take progeny into account that may result in additional impacts to biota.	U/DG	**Tier 1**: Apply concentration levels that effectively disregard the in-growth of progeny	Easily applied approach that is useful for scoping purposes	The concentration limiting value may underestimate overall impact e.g. where sedentary biota close to discharge point are continuously exposed to short-lived radionuclides
			Tier 2: Apply concentration levels that effectively disregard the in-growth of progeny	Easily applied approach that is useful for scoping purposes	The concentration limiting value may underestimate overall impact e.g. where sedentary biota close to discharge point are continuously exposed to short-lived radionuclides

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3: Consider the sensitivity of results to changing assumptions regarding the production and behaviour of radioactive progeny	More complete analysis that will provide the most comprehensive treatment of progeny	Resource-intensive, more complex assessment likely to require expert consultation (e.g. regarding the balance between effective and radioactive half-lives and relevance to life time of biota of interest etc).
Discharge routes					
Impacts on biota in more than one medium/ecosystem	Releases into a medium may have an impact on another. Impacts may be underestimated if impacts on only one ecosystem is considered	DG/U	**Tier 1**: Assume that a single ecosystem is affected (e.g. that into which material is discharged)	Ease and rapidity of assessment. Where assessment indicates no impact on biota in the receiving environment, there can be reasonable certainty that secondary environments would be unaffected.	Incomplete assessment - biota in 'secondary' media may be more significant or more sensitive
			Tiers 2 and 3: Consider impacts on all potentially affected ecosystems, run ERICA for each one and combine as appropriate	This provides a more complete assessment of impact	This approach would require results to be assessed for each ecosystem in turn (and occupancy weighted for biota that exist in more than one ecosystem)
Completeness of conceptual model	All processes involved in the transfer of radioactivity to the environment / biota of concern may not have been considered	U/DG	**Tier 3**: Test predictions from conceptual model to environmental observations	Enables accuracy of model to be verified	Resource intensive.

Issue	Description	Type*	Options	Strengths	Weaknesses
Ecosystem analysis ***Biota characterisation*** Data on presence of species within an ecosystem are unavailable	Presence of sensitive species within the potential impact zone are unknown	DG	**Tier 1**: Use maximum soil, water or sediment concentrations and take 'pessimistic' view that the species are present and assume that at least one organism from the broad suite of ERICA reference organisms is a reasonable surrogate for the actual species present.	Ease and rapidity of assessment - valuable for scoping purposes	The implicit assumption that an assessment species is present may be unreasonable; the overestimation implicitly in the approach may raise unnecessary concerns. The assumption of the presence of particularly sensitive species may result in 'limiting concentrations' being exceeded unnecessarily.
			Tier 2: Identify generic species within the ecosystem type and conduct broad-ranging assessment	Use of default data provides ease of assessment and confidence that choice is based on expert opinion	Generic parameters may not be representative of the designated species present
			Tier 2: Assume the presence of sensitive species and construct a geometry and transfer data relevant for the organism using the 'add organism' functionality	Increases confidence that important biota have been included.	May require expert consultation
			Tiers 2 and 3: Gather information about the species present (and the designation of species and habitats) in the impact zone	This information is readily available and allows more informed development of assessment approach and a focus on designated species	The review and application of site specific information on species type may require consultation with an expert

Issue	Description	Type*	Options	Strengths	Weaknesses
Site designated on basis of habitat qualities rather than species	An assessment may be required to ensure protection of important sites designated for reasons other than the presence of sensitive biota	DG	**Tier 1**: Apply concentration levels that implicitly assume the presence of a generic species relating to the relevant ecosystem type	Ease and rapidity of assessment - valuable for scoping purposes	The species on which this approach is implicitly based may not be representative of the species the designated habitat
			Tier 2: Identify key generic components of the habitat and undertake assessment for these	Simple assessment method that provides assurance that the types of species in the designated area have been considered	This approach will require a review of specific information relating to the habitat. It may also require consultation with experts and stakeholder/conservation groups to ensure acceptability
			Tier 2 and 3: Apply safety factor in applying effects analysis that takes account of uncertainties in extrapolation from population responses to those occurring at higher levels of organisation (see below)	Allows more specific consideration of implications of ecosystem effects	Likely to require consultation with an expert - additional uncertainties will exist that need to be considered
			Tier 3: Identification of species or other assessment endpoint of interest in consultation with stakeholders	Assessment will address specific endpoints of concern to stakeholders	Stakeholder involvement process may be time-consuming and will require expert facilitation
Biodiversity status unknown	Biodiversity rather than specific species/habitats may be of importance	DG	**Tier 1**: Apply concentration levels that implicitly assume the presence of a species for assessment	Ease and rapidity of assessment - valuable for scoping purposes	The species on which this approach is implicitly based may not be representative of the species for which the area is designated
			Tier 2: Identify key species and habitats that have been designated on biodiversity grounds and undertake assessment for these	Simple assessment method that provides assurance that the types of species in the designated area have been considered	This approach will require a review of specific information relating to the habitat. It may also require consultation with experts and stakeholder/conservation groups to ensure acceptability

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 2 and 3: Apply safety factor in applying effects analysis that takes account of uncertainties in extrapolation from population responses to those occurring at higher levels of organisation (see below)	Allows more specific consideration of implications of ecosystem effects	Likely to require consultation with an expert - additional uncertainties will exist that need to be considered
Significance of biota unknown (e.g. designation status)	Where sensitive species are identified, the significance of designation (e.g. locally important/internationally important) may affect the level to which an assessment should be conducted.	DG	**Tier 1**: Apply concentration levels that implicitly assume the presence of a species for assessment	Ease and rapidity of assessment - valuable for scoping purposes	The species on which this approach is implicitly based may not be representative of the species for which the area is designated
			Tiers 2 and 3: Gather information about the species present (and the type of designation of species or habitat, as appropriate)	This information is readily available and allows more informed development of assessment approach and a focus on designated species	The review and application of site specific information on species type may require consultation with an expert
Biota habit data unavailable	Information on the food preferences of identified organisms and occupancy factors within ecosystem compartments are unknown	DG	**Tier 2**: Apply generic habit data for biota type from the ERICA database	Ease of application. Confidence that data has been derived on the basis of expert opinion	The data may not be directly applicable to the biota concerned (significance depends on the designation of biota and predicted dose rates)
			Tier 2: Conduct review to identify similar species and use 'add organism' functionality to assess differences in factors applied.	Increased confidence in assessment through variability analysis	Resource intensive and may require expert consultation

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Assume 100% occupancy in environmental media to which organism will be maximally exposed (e.g. soil / sediment)	Ease of application. Conservative approach.	Could be considered overly conservative.
			Tier 3: Carry out ecological survey to determine site specific data for assessment	Confidence that data will be applicable to the site in question (and applicability demonstrable to stakeholders)	Resource-intensive survey work will need to be undertaken by or in consultation with expert
Geometry of identified biota unknown	Information on the geometry of species and location in surrounding medium is required to assess external dose to biota	DG/V	**Tier 1**: Apply concentration levels that implicitly assume the presence and default geometry of assessment species	Ease and rapidity of assessment - valuable for scoping purposes	The species on which this approach is implicitly based may not be representative of the biota of interest
			Tiers 2 and 3: Gather information on the geometry of biota of interest from literature (at key life stages) and undertake assessment based on this information using data from ERICA or other databases	Database of information available reducing the effort required	Consultation required in defining life-stage that is likely to be of interest (related to effects and radionuclides of concern)
			Tier 3: Undertake uncertainty analysis that takes account of the range of likely geometries	Allows more specific consideration of the likely impact of uncertainties in geometry to be assessed	Resource-intensive and requiring expert consultation.
			Tier 3: Undertake survey of the biota of interest to make more accurate assessment of geometry	More specific to situation being considered	There will be uncertainties related to the natural variability, and design, survey and analysis would also require expert consultation. Resource-intensive.

Issue	Description	Type*	Options	Strengths	Weaknesses
Environment characterisation					
Soil properties/water chemistry unknown	Behaviour of radionuclides within an ecosystem will be dependant upon factors such as pH, oxidation state etc	U/DG / V	**Tier 1**: Apply concentration levels calculated based on generic assumptions regarding soil and water properties	Ease and rapidity of assessment - valuable for scoping purposes	The parameters used in the assessment of concentration values may not be applicable to the environment under consideration (e.g. where characterised by extreme pH, or unusual soil types are present)
			Tier 2: Collect information on the general soil and water characteristics from locally available information & apply appropriate environmental parameters from literature sources in the assessment	Relatively easy assessment that takes account of the type of environmental conditions existing	Information may not be available for the specific radionuclide/biota/environment-type combination
			Tiers 2 and 3: Undertake limited survey to determine soil type/water chemistry characteristics at location of concern and use transfer parameter data for these characteristics (from literature sources)	Provides specific information related to the area of interest with limited additional expenditure	Survey work and interpretation are likely to require consultation with expert
			Tier 3: Undertake survey of environmental characteristics and behaviour of radionuclides of concern and measurement of activity concentrations in environmental media closely related to the primary biota of interest	Provides specific information related to the area of interest, which may be used in probabilistic assessment if appropriate	Sampling programme, survey work and interpretation will be resource-intensive and require consultation with expert

Issue	Description	Type*	Options	Strengths	Weaknesses
Level of background radiation unknown	Level of background radiation will affect the overall dose received by biota	DG	**Tier 1**: Ignore background (or for NORMs do not differentiate between background and man-made contributions)	Easy to apply	The validity of the approach will depend upon the way in which 'concentration limiting values' have been defined
			Tier 2: Derive background doses to biota from information on the average natural background doses experienced by humans in the area and literature-based information for the type of biota of concern	The easiest approach to estimate background doses to biota	Literature information on human and biota background doses will be based on averages that may not be applicable to the biota or area of concern
			Tiers 2 and 3: Derive background dose to biota from data from literature for similar biota and types of environment	Greater specificity of data at moderate effort	The background doses in the area under consideration may vary significantly from information available in literature sources
			Tier 3: Undertake survey to determine the background radiation doses experienced by biota of interest	Demonstrable confidence that data relates to location (and biota) of interest	Resource-intensive survey work will need to be undertaken by or in consultation with expert
Environmental transfer					
Environmental transport					
Dispersion and deposition factors unknown	Radionuclide specific factors unknown - this information is necessary for the calculation of environmental concentrations	DG	**Tier 1**: Ignore deposition and dispersion characteristics by using maximum concentration information for aquatic scenarios (e.g. at point of discharge)	Easy approach to apply - useful for scoping assessment	This approach is likely to lead to significant overestimation of environmental activity concentrations
			Tier 1: Apply IAEA SRS19 model and default parameters to calculate environmental concentrations.	Easy approach to apply.	Does not take account of site specific dispersion

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 2: Generic values may be used from existing tools (including ERICA)	Likely to be more realistic than assuming no dispersion without requiring significant additional work	Continuing uncertainty in detailed pattern of contamination.
			Tier 3: undertake monitoring programme to identify environmental concentrations at locations of interest (such that dispersion and deposition data are not required)	Demonstrable confidence that data relates to location of interest	Resource-intensive survey work will need to be undertaken by or in consultation with expert. The natural variability in dispersion and deposition are likely to give rise to difficulties in sampling to ensure representative results
Activity concentrations present in environment unknown	Activity concentrations in the environment are required for an assessment to be conducted - often this information is interpolated from information on releases to the environment or activity concentrations in other media (e.g. water, soil and sediment)	DG	**Tier 1**: Assume maximum expected concentration in water or soil (from previous experience, authorisation assessments or other relevant information)	Simple screening approach. May be sufficient for low concentration sources	May be over-conservative leading to 'limiting concentrations' being exceeded unnecessarily. Inherent uncertainty in the assessment may reduce stakeholder confidence
			Tier 2: Estimate the activity concentration at location(s) of interest from other information, using dispersion models included in ERICA Assessment tool	This is a useful approach where there is some but incomplete information available (e.g. activity concentrations at point of release but not at the location of biota of interest)	The dispersion assumptions used in this approach do not take account of site-specific topography or surface water conditions.

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Undertake environmental monitoring at the location of the biota of interest	This is potentially the most accurate approach on which to base dose rate or risk assessments	Relatively resource-intensive and it may be difficult to obtain measurement results in environmental materials that exceed detection limits. Sampling programme design would require consultation with an expert.
			Tiers 2 and 3: Conduct robust dispersion modelling taking account of site specific conditions	Provides potentially more accurate assessment of dispersion	Can be resource intensive where models have not been calibrated for the characteristics of the area in question
Kd is unavailable for radionuclide(s) of concern	This information is important for defining the relative amounts of the nuclide in water and sediment	DG	**Tier 2**: Survey recent literature and apply Kd for the radionuclide of concern if available	This approach allows recent information to be taken into account without site-specific survey work	Kds vary significantly depending upon location. It is therefore quite possible that the data in the literature will not be applicable to the situation under consideration
			Tier 2: Extrapolate from information for chemical analogues	This approach may be useful where assessments relate to unusual radionuclides	Kds vary significantly depending upon location. It is therefore quite possible that the data in the literature will not be applicable to the situation under consideration
			Tiers 2 and 3: undertake monitoring programme to measure Kd values	Demonstrable confidence that data relates to location of interest	Resource-intensive survey work will need to be undertaken by or in consultation with expert
Site specific Kd not available for radionuclide	Kd dependant upon soil/sediment/water chemistry	DG/U	**Tier 1**: Apply 'concentration limiting values' that implicitly include default Kd assumptions for the given radionuclide	Easy approach to apply and confidence that default data have been derived on the basis of expert opinion. Useful for scoping assessment	Kds vary significantly depending upon location. It is therefore quite possible that the default data are not applicable to the situation under consideration
			Tier 2: Apply default Kds from literature (including ERICA documentation)	Easy approach apply	Kds vary significantly depending upon location. It is therefore quite possible that the data in the literature will not be applicable to the situation under consideration

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Undertake measurements to determine appropriate site-specific Kds	Demonstrable confidence that data relates to location of interest	Resource intensive in order to ensure that the data are representative of the appropriate conditions
			Tier 3: Gather information on the likely distribution of Kd values to form part of probabilistic analysis	Allows significance of results to the uncertainty in Kds to be studied	Likely to require consultation with experts
Adequacy of models uncertain	Assessment models may not take account of all factors within a system of interest	U	**Tier 2**: Identify and document uncertainty		
			Tier 3: Conduct inter-comparison, for example between site-specific models and default models within ERICA	Provides greater confidence in model outputs	Resource intensive.
Insufficient information on the relationship between habitat and biota monitoring data due to mobility of fauna	Sampled biota may not have been in contact with areas of contamination, site specific CRs may be inaccurate	V/DG	**Tier 2**: Use occupancy data to modify dose rate estimate	Simple approach not requiring additional survey work or other resources	This approach may lead to underestimation of internal dose rate due to oversimplification of distribution of contamination
			Tiers 2 and 3: Undertake a more detailed survey of the spatial range of biota and the extent of contamination. Use these data in exposure assessment	Provides more accurate assessment of exposure	Resource-intensive and requiring expert consultation (e.g. in design and performance of survey work).

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3: Undertake more detailed assessment of the variability of environmental concentration, and of the home range of fauna. Overlay home range data with spatial map of contamination to define degree and modify occupancy factors accordingly.	Provides more accurate assessment of exposure; the distribution information may be used to determine the importance of these uncertainties to the assessment results as a whole	Resource intensive and requiring expert consultation
Concentration Ratio (CR)					
No CR available for organism (for a given radionuclide) in ERICA Assessment Tool	CRs are necessary to estimate internal activity concentrations and doses from general activity concentrations in the environment, i.e. in water or soil	DG	**Tier 1**: The 'limiting' concentration values applied in this tier will be calculated on the basis of default derived CRs	This option is easy to apply; High degree of confidence that values are derived from expert knowledge; Derivation method documented.	Not possible for user to study the sensitivity of results to changing CR assumptions; The applicability of CR may be difficult to defend to non-specialists.
			Tier 2: Review literature for recent CR data and apply if relevant	The review and application of specific and recent information will improve confidence in the assessment	Resource-intensive approach that may require consultation with expert
			Tier 2: Calculate external dose rates only; .	This option is easy to apply and will be a reasonable assumption for many radionuclide/organism combinations for which external dose is the dominant exposure pathway, e.g. gamma emitters and soil invertebrates and zooplankton	This approach may lead to significant underestimation of dose rates for some radionuclides.
			Tier 2: Apply maximum CR or value of 1	Easily applied and provides estimate of dose rate with internal component maximised	Likely to be very conservative for most radionuclides

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Apply CR available for taxonomically similar organism	May be relatively straightforward approach that is easy to justify	Depending on the data available, it may be a more complex decision that may require expert consultation
			Tiers 2 and 3: Apply CR from data for stable isotope	High confidence that the CR will relate closely to the chemical characteristics of the nuclide concerned	Data for stable isotopes may exhibit non-linear transfer behaviour (i.e. CRs are lower at higher concentrations
			Tier 2 or 3: Select CR from analogue (biogeochemically similar) radionuclide	Easily applied for groups of radionuclides with similar environmental characteristics (e.g. actinides)	Extension of this approach beyond defined chemical groups (e.g. actinides) will require consultation with an expert
			Tiers 2 and 3: Application of Allometric Extrapolation Methods	Expert consultation required	
			Tier 2 or 3: Collection of site-specific information	Confidence that the CF will relate to the specific organism and environment (if used in conjunction with generic information). The approach will be particularly important where the radionuclide or environmental conditions are unusual or extreme.	Resource-intensive and, if used in isolation, there may be significant uncertainties resulting from limited sample size and inherent variability of environmental transfers (particularly for bioaccumulation factors for fish tissue)
			Tier 3: Gather information on the distribution of CR values from site-specific information and use this as part of an uncertainty analysis	Allows the significance of these uncertainties to the results to be evaluated	Resource-intensive, expert consultation likely to be required in undertaking appropriate survey work and in undertaking and interpreting results of uncertainty analysis.

Issue	Description	Type*	Options	Strengths	Weaknesses
CR does not take account of natural variability in radionuclide uptake through food preferences etc	Inherent variability in natural populations cannot be accurately modelled by the use of one default CR	V	**Tier 1**: The 'limiting' concentration values applied in this tier will be calculated on the basis of default derived CRs	This option is easy to apply; High degree of confidence that values are derived from expert knowledge; Derivation method documented.	Not possible for user to study the sensitivity of results to changing CR assumptions; The applicability of CR may be difficult to defend to non-specialists.
			Tier 2: Review available literature for information on the variability in CR for biota of interest and apply as appropriate	Data likely to be generally representative of biota of interest; limited resource implications	CRs will still be subject to variability; this approach does not provide a natural basis for uncertainty or sensitivity analysis to determine importance of this variability
			Tier 3: Review information in recent literature on natural variability in CRs to use as basis for uncertainty analysis	Allows sensitivity of results due to variability to be determined (and the basis for prioritisation for further study)	Not site-specific; expert consultation likely to be required
			Tier 3: Collect information on natural variability from site-specific survey information and undertake uncertainty analysis	This approach allows the specifics of the situation to be taken into account, and the influence of uncertainties in CRs to form an explicit part of the assessment	Resource-intensive; The sampling design, performance and interpretation would require expert consultation; the results of the uncertainty analysis may require expert consultation
CR does not take account of natural variability in environmental	Different soil/sediment/water properties will affect CR such as organic content, pH etc	V	**Tier 1**: The 'limiting' concentration values applied in this tier will be calculated on the basis of default derived CRs	This option is easy to apply; High degree of confidence that values are derived from expert knowledge; Derivation method documented.	Not possible for user to study the sensitivity of results to changing CR assumptions; The applicability of CR may be difficult to defend to non-specialists.

Issue	Description	Type*	Options	Strengths	Weaknesses
parameters such as sediment/soil characteristics			**Tier 2**: Review available literature for information on the variability in CR for sediment/soil characteristic of location of interest and apply relevant data in the assessment	Data likely to be generally representative of sediment/soil characteristics of interest; limited resource implications	CRs will still be subject to variability; this approach does not provide a natural basis for uncertainty or sensitivity analysis to determine importance of this variability
			Tier 3: Review information in recent literature on natural variability in CRs due to soil/sediment characteristics to use as basis for uncertainty analysis	Allows sensitivity of results due to variability to be determined	Not site-specific; expert consultation likely to be required
			Tier 3: Collect information on natural variability from site-specific survey information and undertake uncertainty analysis	This approach allows the specifics of the situation to be taken into account, and the influence of uncertainties in CRs to form an explicit part of the assessment	Resource intensive; The sampling design, performance and interpretation would require expert consultation; the results of the uncertainty analysis may require expert consultation
CR not applicable to ecosystem under assessment	Default CR was not derived for the media in question (e.g. river water opposed to lake, estuary opposed to marine)	U	**Tier 1**: The 'limiting' concentration values applied in this tier will be calculated on the basis of default derived CRs (for a generic ecosystem that may similar to that of interest	This option is easy to apply; High degree of confidence that values are derived from expert knowledge; Derivation method documented.	Not possible for user to study the sensitivity of results to changing CR assumptions; The applicability of CR may be difficult to defend to non-specialists.
			Tier 2: Derive appropriate CR from information on the relative values of the CRs in different ecosystems for the biota and radionuclide under consideration	Relatively limited resource requirements	Prone to error - the variation of radionuclide behaviour in different environments is more complex than linear scaling may allow
			Tier 2: Review available literature for information on CRs for the ecosystem of interest and apply relevant data in the assessment	Data likely to be generally representative of ecosystem of interest; limited resource implications	CRs will not represent site-specific features of the ecosystem

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3: Collect information on CR for radionuclide and default biota in ecosystem of interest	This approach allows the specific characteristics of the ecosystem to be taken into account	Resource intensive; the sampling design, performance and interpretation would require expert consultation; the results of the uncertainty analysis may require expert consultation
Default CR uncertain	lack of data for the derivation of default CR values within ERICA tool required data manipulation (e.g. extrapolation of single tissue concentration data to whole organism concentrations, application of soil depth and density data to convert Bq/m2 data to Bq/kg etc) leading to uncertainties in applicability of default factors.	U	**Tier 1**: The 'limiting' concentration values applied in this tier will be calculated on the basis of default derived CRs	This option is easy to apply; High degree of confidence that values are derived from expert knowledge; Derivation method documented.	Not possible for user to study the sensitivity of results to changing CR assumptions; The applicability of CR may be difficult to defend to non-specialists.
			Tier 2: Select most appropriate ERICA CRs using selection criteria made available in the tool	Limited resource requirements. Enables most applicable selection criteria to be selected for the particular assessment. User-defined CR values can be entered where site-specific values are available.	
			Tier 3: Derive site specific CR	Increases confidence in applicability of CR value	Resource intensive. Approach cannot be applied to rare or endangered species
			Tier 3: Run assessment with various CR values to determine sensitivity of dose to changes	Increased confidence in assessment through variability analysis	Resource intensive, requires multiple assessments to determine variability

Issue	Description	Type*	Options	Strengths	Weaknesses
Whole organism concentration data unavailable	CRs are required on basis of whole organism concentrations for assumption of uniform distribution within the ellipsoid geometry	DG	**Tiers 2 and 3**; Apply most applicable ERICA default CR values	High degree of confidence that values are derived from expert knowledge. Derivation method documented.	Doesn't allow for site-specific factors to be taken into account.
			Tiers 2 and 3: Apply assumptions used by experts in derivation of ERICA default CRs to available site-specific data	Enables site-specific factors to be taken into account	Resource intensive. Could be open to greater criticism from stakeholders.
Accumulation of radionuclides within biota tissues	Methodology requires assumption of uniform distribution within the ellipsoid geometry so does not take account of accumulation within organs.	U	**Tiers 2 and 3**: Where organ of accumulation could result in greater effect that that estimated (e.g. reproductive organs), run assessment using geometry applicable to the organ in which accumulation occurs.	Increased confidence that impact will not be underestimated	Requires additional assessment and more considered interpretation of results
Reference organism					
Reference organisms are not applicable to the ecosystem requiring assessment	Biota present within a site cannot be assessed due to lack of a suitable reference organism within the habitat type	DG	**Tier 1**: Apply 'limiting concentration levels' that implicitly assume the presence of a reference organism for defined ecosystem types	Ease and rapidity of assessment - valuable for scoping purposes	The implicit assumptions underlying the specification of the reference organism may be applicable to the species present in the habitat of interest
			Tier 2: Identify Reference Organism analogue for the biota of interest and apply relevant parameters (e.g. most suitable geometry and taking account of mass/volume) in assessment	Data likely to be generally representative of biota of interest; limited resource implications	Specifics of reference organism assumptions may not be applicable to biota of interest

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Identify geometry related to biota (and life-stage of interest), assess external rates using the DCC tool	Relates to specific characteristics of the biota of interest	Resource intensive; expert consultation necessary for calculations
Reference organisms not representative of those species requiring protection under European and National legislation	Lack of specific reference organisms for internationally important species as designated under both national and international legislation may lead to their exclusion from assessments	DG	**Tier 1**: Apply 'limiting concentration levels' that implicitly assume the presence of a reference organism for defined ecosystem types (using DCC Tool)	Ease and rapidity of assessment - valuable for scoping purposes	The implicit assumptions underlying the specification of the reference organism may be applicable to the species present in the habitat of interest
			Tier 2: Interpolate from existing information based on available reference species with similar attributes (using DCC Tool)	Relatively easy to apply; possible to take account of general characteristics of the biota of interest (e.g. life cycle, habits for organism type)	Data not specific to biota of interest; Applicability may be difficult to demonstrate
			Tier 3: Gather information on the geometry and behaviour of the organism of interest and apply the most applicable geometry from the default set of reference organisms and undertake uncertainty analysis to account for any variation in geometry between default and actual organism.	More accurate assessment that takes account of the specific nature of the species concerned without need for site-specific monitoring	The default data will not fully represent the characteristics of the species concerned.
			Tier 3: Collect information for relevant biota of interest and use this information to undertake assessment (with help of DCC Tool)	Specific to the biota of interest	Resource-intensive; all stages of assessment require expert consultation

Issue	Description	Type*	Options	Strengths	Weaknesses
Natural variability in mass/volume not reflected in reference organism geometry	External doses may be over/under estimated depending on variation in biota/reference organism geometries	V	**Tier 1**: Apply 'limiting concentration levels' that implicitly assume the characteristics of a reference organism for defined ecosystem types	Ease and rapidity of assessment - valuable for scoping purposes	The implicit assumptions underlying the specification of the reference organism may be applicable to the species present in the habitat of interest
			Tier 2: Review available literature for information on the variability in biota geometry and apply data as appropriate	Data likely to be generally representative of biota of interest; limited resource implications	Geometry will still be subject to variability; this approach does not provide a natural basis for uncertainty or sensitivity analysis to determine importance of this variability
			Tier 3: Review information in recent literature on natural variability biota geometry to use as basis for uncertainty analysis	Allows sensitivity of results due to variability to be determined	Resource-intensive. Not site-specific; expert consultation likely to be required
			Tier 3: Collect information on biota geometry and undertake uncertainty analysis	This approach allows the specifics of the situation to be taken into account, and the influence of uncertainties in CRs to form an explicit part of the assessment	Resource-intensive and difficult to design and undertake. The sampling design, performance and interpretation would require expert consultation; the results of the uncertainty analysis may require expert consultation

Issue	Description	Type*	Options	Strengths	Weaknesses
Species identified for assessment span more than one ERICA ecosystem	Biota may spend time in more than one ecosystem (e.g. transition zones such as marsh areas where exposures could be high due to nuclide accumulation) or there may be different biota that need to be assessed in different ecosystems	DG/U	**Tier 1**: Apply 'limiting concentration levels' in the primary ecosystem of concern (e.g. that into which radionuclides are discharged)	Ease and rapidity of assessment - valuable for scoping purposes	Incomplete assessment which may result in significant errors due to important biota groups not being included in the assessment
			Tier 2: Consider biota present in different ecosystems and assess based on assessed dose rates in each ecosystem or occupancy-weighted sum of dose rates, as appropriate	Errors reduced by taking account of combinations of ecosystems; easily applied if information available for biota-type in ERICA-defined ecosystems	Requires multiple runs of ERICA Tool and the combination of results external to tool
			Tier 3: Undertake site-specific assessment of biota that takes account of multiple ecosystem occupancy and different biota present in different ecosystems	Specific to ecosystems of interest	Resource-intensive
Geometry does not take account of varying geometries of different biota life stages	Different life stages may vary in their sensitivity to the effects of radiation exposure	V	**Tier 1**: Apply 'limiting concentration levels' that implicitly assume the characteristics of a reference organism for defined ecosystem types	Ease and rapidity of assessment - valuable for scoping purposes	juvenile stages may be maximally exposed due to habits and geometry, which may be underestimated through use of reference organism approach based on adult stage
			Tiers 2 and 3: Investigate effects data to determine the most sensitive life-stage to help guide information gathering with respect to geometry	Allows a more focused approach	Resource-intensive and interpretation of the corresponding effects data likely to require expert consultation

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Collect information from literature on the geometry of the biota of interest under various life-stages and use to undertake assessment using the DCC Tool and combine as appropriate	Errors reduced by taking account of combinations of ecosystems; easily applied if information available for biota-type in ERICA-defined ecosystems	Requires multiple runs of ERICA Tool and the combination of results external to tool
Suitable geometry data not available for user-defined species of interest	Accurate dimensions for ellipsoid axes and mass not available on which to calculate user-defined geometry	DG	**Tier 3**: Identify most applicable data and apply expert judgement to define those for which data are lacking	Easy to apply	Subject to error and uncertainty
			Tier 3: Monitor species of interest to derive required data	Enables high degree of certainty in derived data and enables variability in dimensions and mass to be taken into account	resource intensive
Dose Conversion Coefficient (DCC)					
No external DCC for radionuclide/organism	External dose cannot be calculated for the radionuclide/organism combination	DG	**Tier 2**: Apply information from radionuclide/reference organism combinations that are likely to have similar external DCCs	Easy to apply; useful as initial scoping approach	Assessment based on external dose alone (significant error where internal doses likely to be significant); interpolation on more than one parameter is prone to error
			Tiers 2 and 3: Collect information from literature on the geometry of the biota of interest and use to undertake assessment using the DCC tool	Undertake specific assessment based on generic geometry information included in ERICA Tool	May require expert consultation
			Tier 3: Conduct dose rate measurements at the site of interest	Data specific to site of interest	May be incomplete assessment if internal dose is likely to be significant contributor to dose; Design, sampling and interpretation will require expert consultation

Issue	Description	Type*	Options	Strengths	Weaknesses
Variability in organism dimensions and mass	Reference geometry is not precise for a specific organism leading to uncertainty in the DCC	V	**Tier 3**: Assign probability distributions	Allows variability to be taken into account	
Organ specific information	Organ-specific dose rates may be necessary for accurate assessment of effects e.g. where reproduction is the primary endpoint of concern	DG	**Tier 1**: Apply 'limiting concentration levels' that implicitly assume effects related to dose rates to whole body	Ease and rapidity of assessment - valuable for scoping purposes	Errors in assessment of effects (e.g. if reproduction is the primary endpoint of concern)
			Tier 3: Undertake specific dose rate assessment based on whole body and/or organ-specific information and prediction of effects based on information in FREDERICA	Accounts for effects at an organ-specific level	Potentially resource-intensive. Limited information likely available to support dose rate calculation or effects analysis. Expert consultation necessary
No DCC for internal exposure	Internal dose cannot be calculated for the radionuclide/organism combination without DCC for activity concentrations internal to the organism	DG	**Tier 2**: Ignore internal dose component and calculate dose rates based on external dose alone	Simple to apply where external DCCs exist	Dose may be under estimated due to exclusion of either internal or external dose from calculations
			Tiers 2 and 3: Gather information from literature, specify organ size and shape and use ERICA Assessment Tool to derive DCC for internal exposure	More complete assessment that takes account on internal dose component	Expert consultation necessary to determine data requirements and apply model

Issue	Description	Type*	Options	Strengths	Weaknesses
Ecosystem					
Ecosystem to be assessed is not covered by ERICA	Not all important habitats can be accurately assessed using the assessment method - e.g. salt marshes	DG/U	**Tier 1**: Apply 'limiting concentration levels' in the ERICA ecosystem closest to that of interest	Ease and rapidity of assessment - valuable for scoping purposes	Errors in assessment likely to arise due to the inability to take account of ecosystem specifics (e.g. salinity, occupancy)
			Tier 2: Gather information from literature on the likely difference in environmental behaviour between ERICA defined-ecosystem and the ecosystem of interest and apply appropriate factors	Relatively easy to apply while allowing partial account of characteristics of ecosystem of interest	Information likely to be limited and to require expert consultation
			Tier 3: Undertake site-specific surveys to gather information necessary for assessment	Demonstrably confident that information specific for ecosystem	Resource-intensive - requiring expert consultation and involvement
Effects analysis					
No effects data for wildlife group of interest	Lack of effects data will reduce the level to which it is possible to make specific statements about the acceptability, or not, of a given situation	DG/U	**Tier 2**: Compare calculated dose with the lowest causing effect in all biota categories	Cautionary approach - where calculated dose is below all effects data there can be confidence in the conclusion of no impact	The effects data will not necessarily be representative of the biota under consideration. Possible over-estimation
			Tiers 2 and 3: Extrapolate effects data for similar organisms (and take account of uncertainties by using appropriate safety or extrapolation factor)	Allows effects to be evaluated without the need for additional effects studies or site-specific surveys (NB: it will not be possible to collect specific data for protected species the use of information for analogous species is likely to be the only option in most cases)	There will be significant uncertainties associated with extrapolating information from one species to another. Simple extrapolation factors are a semi-quantitative conservative approach to taking account of uncertainties

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Extrapolate effects data for similar organisms using information from the FREDERICA database to construct species sensitivity distribution for appropriate taxonomic group	Refined quantitative analysis of extrapolation between species	Other uncertainties remain (SSD will only taken account of extrapolation between species).
			Tier 3: Conduct survey and analysis to develop effects analysis information that is more relevant to the group of interest	Demonstrates completeness of assessment (assuming that a proportionate approach is applied to all parameters in the assessment)	The collection of more representative wildlife group or site-specific information will need to be undertaken by experts. Uncertainties will still exist due to the extrapolate information for protected species; uncertainty analyses would also require significant expert consultation.
Multi-stressor context	The presence of additional non-radioactive stressors may result in a given dose rate having a greater or lesser effect than predicted (if the environment is under significant stress)	DG/U	Additional safety factors may be used (in all Tiers) to take this issue into account and ensure conservatism	Allows a semi-quantitative assessment of the effect of multiple stressors for limited additional resource	The safety factor approach is arbitrary and a significant source of uncertainty only partially taken into account
			Tier 1: Mention the possibility of additional stressors but do not make any quantitative assessment of combined stress	This demonstrates that other issues have been considered but does not require additional assessment resources	This does not provide a complete assessment
			Tier 1: Undertake assessment of the impact of radionuclides using ERICA and identify other stressors present and apply Environmental Quality Standards for these pollutants	This demonstrates that other issues have been considered and requires limited additional assessment resources	This approach does not provide a combined assessment of impact

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3: Use information on the contaminants present in the environment and from literature sources to derive probability distributions that account for the uncertainty in effects due to the presence of additional stressors	Distribution information will allow the significance of this source of uncertainty to be evaluated	Resource-intensive survey work likely to require expert consultation
			Tier 3+: Assess the combined impact of environmental stressors using biomarker methods (in consultation with relevant expert)	This approach has the potential to provide a complete assessment that addresses all stressors on biota under consideration	Very resource-intensive. There remain significant uncertainties regarding the interpretation of biomarker results. For example the extent to which they relate to health impacts exhibited in individuals or populations, and in the identification of relative importance of different types of stress. This approach may imply significant research involvement
Toxic radionuclides (e.g. U) not accounted for by dose	Increased impact may occur where radionuclides present both radio- and chemical toxic effects	U	All tiers: Ignore the potential for toxic impacts and apply 'limiting concentration levels' that implicitly to the ERICA ecosystem closest to that of interest	Ease and rapidity of assessment - valuable for scoping purposes to indicate radiological impacts	Could lead to significant underestimation of potential effects for some radionuclides (e.g. uranium)
			All tiers: Conduct review to determine whether toxicity likely to occur at media concentrations calculated	Demonstrates that potential toxic effects have been considered without significant increase in effort	Only qualitative consideration of potential effects (not possible to comment on antagonistic or synergistic impact)

Issue	Description	Type*	Options	Strengths	Weaknesses
Application of weighting factors uncertain	RBE of alpha radiation on non-human biota uncertain - for non-human biota RBEs for alpha and beta radiation vary between species, life stages, endpoints and exposure regime	U	**Tier 1**: Apply 'limiting concentration levels' that implicitly include default weighting factor assumptions	Ease and rapidity of assessment - valuable for scoping purposes to indicate radiological impacts	Does not provide basis for considering relative importance of uncertainties in weighting factors to other assessment issues
			Tiers 2 and 3: Calculate and present dose rates separately for high and low LET radiation	Transparent approach that allows users to understand the contribution of different types of radiation, and to externally apply weighting factors as appropriate	Dose rate results do not provide complete indication of potential effects - additional interpretation is required
			Tiers 2 and 3: Apply various weighting factors in order to determine impact on calculated doses	Allows statements to be made regarding the importance of results to with respect to weighting factors	There is the potential for overestimation of doses from alpha radiation by use of very high weighting factors
Application of acute/chronic effects data	Effects information is generally available for high doses and dose rates - it may be necessary to extrapolate these data to chronic/low dose rate situations	U	**Tier 1**: Apply 'limiting concentration levels' that implicitly include default assumptions to provide screening values for both acute and chronic situations	Ease and rapidity of assessment - confidence that effects data judgements have been made on the basis of expert opinion	It is not possible to make specific statements regarding the applicability of effects data to the situation under consideration
			Tier 2 : Calculation of dose rates to biota of interest using the standard features of the assessment tool; review information available in the FREDERICA data base (or from more recent publications if available) on effects for the biota type and make qualitative statement about applicability to situation being considered	Demonstrates that this issue has been considered with relatively limited effort; provides an additional basis for determining whether **Tier 3** assessment is required	This allows only qualitative consideration of one of the most significant uncertainties related to effects analysis

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tiers 2 and 3: Application of extrapolation factor or safety factor by determining relationship between chronic and acute effects within FREDERICA database for alternative biota categories	Relatively simple quantitative evaluation of chronic effects from acute data which could provide information needed for uncertainty analysis (safety factors of power of 10 often applied; where several extrapolation multiple factors will be applied).	Some expert judgement will be needed to apply such factors
			Tier 3: Take account of uncertainty in extrapolation from acute to chronic effects in the specification of distribution on the probability of effects, as part of uncertainty analysis	Demonstrates completeness of assessment (assuming that a proportionate approach is applied to all parameters in the assessment)	Resource-intensive requirements for specification and application of uncertainty analysis; consultation with an expert necessary
Extrapolation required between individual effects and population	There is often more information available on individual responses rather than on populations. It may be necessary to extrapolate from information on individuals to assess population-related effects	DG/U	**Tiers 2 and 3**: Apply safety factor to allow for the uncertainty in extrapolating from individual to population responses	Relatively simple quantitative evaluation (safety factors of power of 10 often applied; where several extrapolation multiple factors will be applied).	Some expert judgement will be needed to apply such factors
			Tiers 2 and 3: Apply population dynamic modelling approach (e.g. Leslie Matrix) to predict population response	More accurate assessment of potential population effects without detailed survey requirements	Analysis will need to be performed by an expert
			Tier 3: Take account of uncertainty in extrapolation from acute to chronic effects in the specification of distribution on the probability of effects, as part of uncertainty analysis	Demonstrates a relatively complete assessment possibly without the need for additional survey work (assuming that a proportionate approach is applied to all parameters in the assessment)	Resource-intensive requirements for specification and application of uncertainty analysis; consultation with an expert necessary

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3: Specific experimental study, including the consideration of population dynamics	A complete assessment of the likely effects on a population level	There will still be uncertainties involved in the effects analysis (e.g. due to species extrapolation and dose rates) due to experimental design requirements. Population dynamic information may be difficult to collect. Such experiments would need to be performed by experimental scientists.
Reliability of effects data unknown	Test conditions on which effects data are reported are not known (e.g. proportion of the population tested, genetic factors etc) leading to uncertainty in their reliability	U	**Tiers 2 and 3**: Apply safety factor to allow for the uncertainty	Relatively simple quantitative evaluation (safety factors of power of 10 often applied; where several extrapolation multiple factors will be applied).	Some expert judgement will be needed to apply such factors
Basis for organism effects data uncertain	Life stage of test organism on which effects data are available is not reported leading to uncertainties in the interpretation of effects results (sensitivity of life-stage unknown)	U	**Tiers 2 and 3**: Apply safety factor to allow for the uncertainty	Relatively simple quantitative evaluation (safety factors of power of 10 often applied; where several extrapolation multiple factors will be applied).	Some expert judgement will be needed to apply such factors
Extrapolation of population information to higher organisational levels	Derived benchmarks are based on ecotoxicity data observed at the individual level	U	**Tiers 2 and 3**: Application of safety factor to take account of extrapolation to higher levels of organisation and ensure conservative approach	Allows effects to higher organisational levels to be taken into account in simple approach	Safety factors will tend to overestimate effects

Issue	Description	Type*	Options	Strengths	Weaknesses
			Tier 3: Undertaken predator/prey modelling to refine benchmarks and application of ecologically relevant weight to each trophic level	Improves realism of approach (where the ecosystem is well characterised)	Will require consultation with an expert
Application of laboratory information	Extrapolation between laboratory and field data will not take account of multi-stressor effects or differences in sensitivity between laboratory and field organisms	U	**Tiers 2 and 3**: Apply safety factor to allow for the uncertainty in extrapolating from individual to population responses	Simple approach that allows effects data to be derived from the widest database of information available	There will be uncertainties resulting from application of laboratory data to field situations due to additional stresses in field conditions (e.g., competition, predation, effects from other pollutants) but safety factors tend to be conservative
			Tiers 2 and 3: Review information available in ERICA database and other literature sources to determine whether it would be possible to apply a factor to allow for extrapolation errors	Simple semi-quantitative approach providing some allowance for this source of uncertainty and the basis for further study (e.g. consideration of uncertainty analysis)	The relationship between effects under field and laboratory conditions is likely to be complex and vary for different species. There is unlikely to be information sufficient to support the use of a single factor. Expert interpretation will be required.
			Tier 3: Take account of uncertainty in extrapolation from laboratory to field effects studies in the specification of distribution on the probability of effects, as part of uncertainty analysis	Demonstrates completeness of assessment (assuming that a proportionate approach is applied to all parameters in the assessment)	Resource-intensive requirements for specification and application of uncertainty analysis; consultation with an expert necessary

Issue	Description	Type*	Options	Strengths	Weaknesses
Implications of bystander effects, secondary responses and genomic instability	Such effects may lead to additional uncertainties assessing effects on individuals from radioactive and chemical pollutants, particularly at low dose rates	U	**Tiers 2 and 3**: Do not take account of these effects in quantitative assessment but make statement regarding this type of uncertainty	Demonstrates that issues have been considered at minimal additional effort	May reduce confidence in assessment results (where other sources of uncertainty are generally likely to be more significant)
			Tier 3: Allow for uncertainties in effects analysis due to such effects from information available in literature	Demonstrates completeness of assessment (assuming that the approach to other uncertainties is similarly detailed)	Difficult to incorporate simply in uncertainty analysis. Information available on the level of uncertainty associated with such effects would need to be interpreted by an expert and the results are likely to be difficult to explain to non-specialists
Interpretation and Evaluation					
Generic 'Benchmarks' do not take account of site-specific issues in the assessment	All generic criteria or benchmarks are derived on the basis of assumptions that may not apply to the situation in question	U/V	**Tier 1**: Apply 'limiting concentration levels' defined in the ERICA tool and comment on uncertainties involved	Confidence that these values will have been derived based on expert opinion	Simple application of these levels does not allow uncertainties to be specifically addressed
			Tier 2: Apply 'benchmark' directly but comment on the uncertainties involved **Tier 2**: Apply safety factor to 'benchmark' dose rate to account for uncertainty	Simple approach not requiring additional resources Simple approach to apply that takes account of uncertainty	No account of uncertainties. This may lead to the results being questioned. Specification and application of safety factors is arbitrary and likely to be conservative (e.g., in comparison with values based on species sensitivity distribution information

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			Tier 2: Derive benchmark based on predicted no-effects dose(rate) levels identified from FREDERICA database	More specific account of the form of information available for the particular biota group	Data requirements more extensive than safety factor approach. Data evaluation and interpretation are complex requiring consultation with experts
			Tiers 2 and 3: Derive benchmarks based on species sensitivity distribution based on a percentile of the SSD for a subset of the FREDERICA database (for particular taxonomic grouping)	More specific account of the form of information available for the particular biota group	Data requirements more extensive than safety factor approach. Data evaluation and interpretation are complex requiring consultation with experts
			Tiers 2 and 3: Derive a 2 tier benchmark approach based on two different criteria for the percentage of species protected	Initial lower trigger level allows more structured decision with regard to the extent of impact and the specific effects on ecosystem stability and biodiversity effects	Resource-intensive approach requiring expert consultation
			Tier 3: perform assessment that includes uncertainty analysis and species sensitivity distribution information (related to the appropriate trophic level)	More accurate statement of the implications of the assessment (including possibility of taking account of organ-specific responses and specific trophic/taxonomic groups)	Specification of parameter distributions and analysis will need to be performed by an expert
Assumptions implied in defining a criterion may not be applicable to the situation under consideration	The criterion may relate to a pathway or organism that is not present	U	**Tier 2**: Modify benchmarks to more closely reflect the situation under consideration (e.g. biota or habits considerations) using information available in the FREDERICA database.	Benchmark will more clearly relate to specifics of situation	Requires consultation with an expert (and appropriate stakeholders and authorities)
			Tier 3: Perform more site-specific assessment to determine the likely effects from information from the FREDERICA database	Results more representative of the current state of knowledge about the organism concerned	More resource-intensive - likely to be warranted only if concentrations significant or there is stakeholder concern

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Treatment of natural background in deriving benchmarks	There may be errors associated with the treatment of natural background due to uncertainty in conditions in which experimental effects data have been derived	U	**Tiers 2 and 3**: Derive benchmarks or effects data based on laboratory studies where background is excluded include natural background in the assessment of exposure (dose rate)	Confidence that data set consistent with consideration of total exposure; single value benchmarks may be defined	Reduction in the dataset used to define benchmarks, uncertainties still remain that will need to be addressed (e.g. by safety factors), expert consultation required
			Tiers 2 and 3: Apply 'added risk approach' that involves in assessment the component of dose or concentration above background for comparison	Similar to approach adopted for humans, background may be used as additional comparator	Exposure analysis potentially more complex requiring evaluation of local background for subtraction from measured data; uncertainty remains about applicability of effects information