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PROTECT

Protection of the Environment from Ionising Radiation in a Regulatory Context

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Workshop: Approaches to demonstrate protection of the environment from ionising radiation (27th-29th June 2006, Vienna, Austria)

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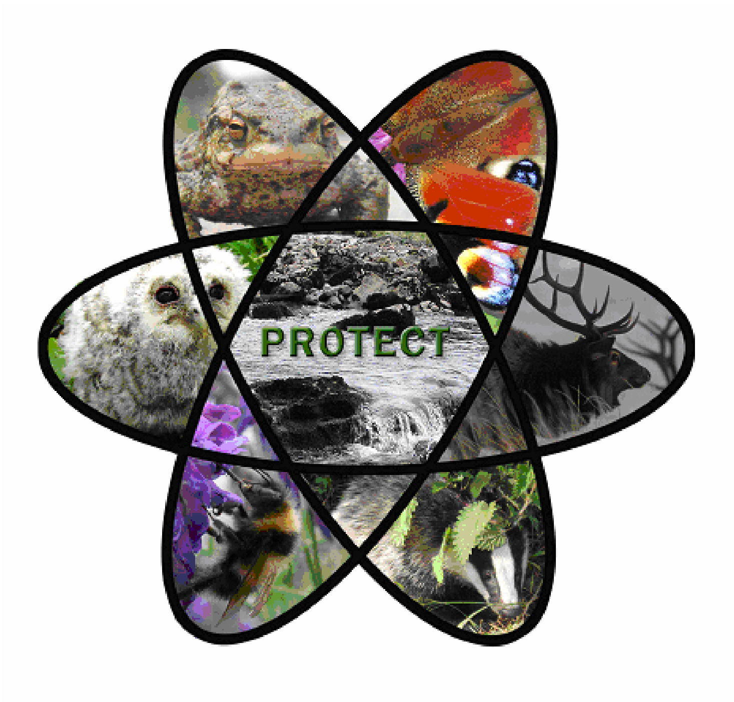
The EU EURATOM funded PROTECT project (FI6R-036425) will evaluate the different approaches to protection of the environment from ionising radiation and will compare these with the approaches used for non-radioactive contaminants. This will provide a scientific justification on which to propose numerical targets or standards for protection of the environment from ionising radiation.



Project Co-ordinator: Natural Environment Research Council, Centre for Ecology & Hydrology

Contractors:

Natural Environment Research Council, Centre for Ecology & Hydrology	(CEH)
Swedish Radiation Protection Authority	(SSI)
Environment Agency	(EA)
Norwegian Radiation Protection Agency	(NRPA)
Institute for Radiological Protection and Nuclear Safety	(IRSN)

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Kathy Higley	ICRP, International
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1. Purpose of the Workshop

The purpose of this workshop (the first of two within work package 2) was to begin evaluation of the approaches available for use in the demonstration of the protection of the environment from ionising radiation. The workshop brought together developers of key approaches and current and potential users of these approaches. Specific objectives of the workshop were to:

- Discuss how the approaches are being used in assessments
- Identify areas which work well and those which require improvement
- Begin to assess the relevance (and applicability) of the approaches to third parties.

A proportion of the workshop was devoted to the application of three approaches, which are readily available to users, to a simple scenario.

This report records the discussions during the workshop, the results and follow-up evaluation of the scenario application and points for consideration by the PROTECT consortium arising from the workshop.

A second workshop will be held for this work package in Oslo 28th-30th January 2008; to register an interest, contact Nick Beresford (email:nab@ceh.ac.uk).

1.1 Report format

The workshop opened with a number of presentations which focused on application and development of approaches for demonstrating protection of the environment from ionising radiation. The presentations can all be viewed on-line (see agenda below), the following section of this report documents discussions after each of the presentations. Subsequent sections are devoted to the scenario application conducted during the workshop (Section 3) and the final discussion session of the workshop (Section 4). Discussion sessions are recorded anonymously, points made during these discussions do not necessarily reflect the views of members of the PROTECT consortium. It is now for the PROTECT consortium members to review and extract relevant information for PROTECT from the record of the meeting for use in the other phases of the PROTECT project. Points of clarification are presented in parenthesis using italicised text.

1.2 Agenda

When reading this document electronically, presentations made at the workshop can be accessed by clicking the title within the agenda below (all presenters agreed to make the presentations available in this way).

	Wednesday 27/06/07	
13:30	Welcome and overview of PROTECT	Brenda Howard (CEH)
14:00	Work package 1 – results from questionnaire and overview of tools used in chemical assessments	David Copplestone (EA)
14:30	Work package 2 - objectives	Nick Beresford (CEH)
15:15	Application of RESRAD-BIOTA for a site-specific ecological risk assessment and the development of radiological tissue guidelines for aquatic organisms	Jing-Jy Cheng (ANL)
15:45	The Canadian experience – estimating radiation hazards to biota at uranium mines	Steve Mihok (CNSC)
16:15	The LIETDOS assessment approach to environmental protection from ionizing radiation in Lithuania	Tatjana Neveckaite (Inst. of Physics)
16:45	Ecological Linkages in Risk Assessment: Evaluating Risk in Natural Ecosystems	Tamara Yankovich (AECL)
	Thursday 28/06/07	
09:00	Conclusions of the ERICA case study assessments	Brenda Howard (CEH)
09:30	Application of R&D 128 to Natura 2000 sites	David Copplestone (EA)
10:00	Radioprotection of the environment in France: IRSN current views and workplan	Karine Beaugelin-Seiller (IRSN)
11:00	Development of a dynamic assessment model	Jordi Vives i Batlle (WSC)
11:30	Experience assessing routine liquid effluent discharges from a Research Reactor - stringing together available software	John Ferris (ANSTO)
12:00	Experiences of applying R&D128, the ERICA-Tool and RESRAD BIOTA	Mike Wood (University of Liverpool)
13:30	EMRAS Biota Working Group – main findings	Nick Beresford (CEH)
14:00	ICRP – intentions and requirements	Kathy Higley (ICRP)
15:00	Scenario description	David Copplestone (EA)
15:15	Scenario application	All
	Friday 29/06/07	
09:00	Complete scenario application	All
11:00	Report back on scenario application	
13:00	Discussion	
15:00	Workshop round-up	
15:30	Close	

2. Discussion of Presentations

Discussion following each presentation is presented where appropriate.

2.1 Work package 1 – results from questionnaire and overview of tools used in chemical assessments (D. Copplestone)

It was queried whether the EUSES software could be used to implement the approaches from the EU Technical Guidance Documents (e.g. species sensitivity distributions). Subsequent to the workshop it has been confirmed that the EUSES software is available for download free of charge from and is based on the EU Technical Guidance Documents (TGD) on Risk Assessment for New Notified Substances, Existing Substances and Biocides. The new EUSES 2.0.3 version (2005) has been updated according to the revision of the TGD on Risk Assessment although the EUSES software is primarily designed for initial and refined risk assessments rather than comprehensive ones.

2.2 Application of RESRAD-BIOTA for a site-specific ecological risk assessment and the development of radiological tissue guidelines for aquatic organisms (J-J. Cheng)

There was a discussion regarding heterogeneous distribution of depleted uranium (DU). It was thought relevant to use 90th percentile and median rather than maximum and mean concentrations, as the highest concentrations were coupled to large fragments for which the concentration ratio (CR) values would not be applicable. A general comment was that one has to be cautious when dealing with heterogeneous distributions making sure that choice of diet, occupancy factors and other parameters are not correlated to the distribution. The direct ingestion/uptake of particle fragments was not assessed, but was considered to be dealt with by using the 90th percentile values, as these represented samples dominated by DU fragments.

For uranium, it was noted that concentrations dealt with when assessing and regulating uranium mines are quite a lot higher than many cases dealing with "anthropogenic uranium". The predominance of chemotoxicity over radiotoxicity (of DU) was acknowledged, but the chemotoxicity assessment of the site was conducted separately and not reported at this meeting.

As the soil colour was affected at the location where the DU penetrators were found it was suggested that this might influence how biota might interact with the area.

In the development of radiological tissue (activity concentration) guidelines for marine organisms, soil K_d values and not marine sediment K_d values were used. It was suggested that this could have a considerable influence on the results. In response it was stated that the work described was focused on method development and not on obtaining specific values at this stage.

2.3 The Canadian experience – estimating radiation hazards to biota at uranium mines (S. Mihok)

A question was raised on how protected species were treated, but this had not yet been necessary to consider in Canada (with respect to U mining) (*protected species in Canada are protected at the individual level*). There was a discussion on which species should be assessed, as it is not possible to study everything in detail. In Canada, species are chosen both from a scientific point of view and from public interest and are classified as valued ecosystem components. This differs from the concept of reference organisms, as in Canada, the focus has been on species of interest locally (*although in selecting these consideration is given to ensuring a cross-section of exposure pathways, trophic positions, radionuclides etc. are taken into account*).

The major problem with the evaluation of radiation hazards to biota at uranium mines is the lack of measurement data for both the activity concentrations in the biota and also on any observed effects of the exposure on the biota. It was noted that the screening levels used in the current generation of tools are likely to give rise to very high exceedances as measured by the risk quotients because of the high degree of conservatism built into the tools. This means that in most cases, there is a need to move beyond a screening approach to a site-specific evaluation and this is where the lack of data becomes a limiting factor in undertaking the assessments.

Some issues were also reported where the assessments fail to take into account all possible pathways, again often linked to the lack of base data on which to build appropriate assessments.

2.4 The LIETDOS assessment approach to environmental (T. Nedvekaite)

A paper on the application of this approach to the cooling ponds at the Ignalina NNP is now available on-line (Nedveckaite et al. (in press)).

2.5 Ecological Linkages in Risk Assessment: Evaluating Risk in Natural Ecosystems (T. Yankovich)

The question was asked whether the consideration of exposure of aquatic biota from contaminated plants was significant. It was acknowledged that in most circumstances it is not. However, for organisms living in areas of dense macrophytes and for radionuclides for which the macrophyte:water concentration ratio was greater than 1, then it could significantly to external dose.

It was commented that the tiered approach resembled that of other tools and that the use of distribution factor was to give a maximum concentration in any tissue leading to a hyper-conservative approach in the screening method is applied.

Again, the difference between concentrations around uranium mines and NPPs was highlighted by a member of the audience. Whereas on NPP-sites it is possible to be hyperconservative and be able to screen out sites due to low potential risk, such an approach was stated to not be useful around mines, as Tier 1 assessments would always fail (i.e. result in risk quotients in excess of one). This last point is one that should be highlighted to WP3 when they consider the significance and use of different types of screening values.

2.6 Conclusions of the ERICA case study assessments (B.J. Howard)

Clarification was requested as to why the Cs concentration in sea birds was 500 times over-predicted during the ERICA Sellafield marine case study application. It was answered that the available data were for species of gull, which were likely to also feed in the (comparatively less contaminated) terrestrial ecosystem.

The origin of the effects data for Komi was queried, as from the questioner's previous knowledge there appeared to be a considerable amount of data available for this site, but little of this appears to be useful. Furthermore, the area will be contaminated by many chemical pollutants (e.g. Pb) originating from uranium industries, whereas the data concentrate on radiological effects. In response, it was stated that NRPA had gained access to a considerable amount of 'grey literature' via the (Komi) Institute of Biology. However, it was acknowledged that the ERICA assessment had not considered chemical toxicity although the report does note that this was not considered in the assessment and that the chemical toxicity of (Th and U) is likely to be more important than radiotoxicity.

Explanation of the uncertainty factor used in Tier 2 and why this was anticipated to result in a value close to the 95th percentile using Tier 3 was requested. In reply it was explained that the ERICA-Tool reports a 'best estimate' dose rate and a 'conservative dose rate' estimated by applying an uncertainty factor. An uncertainty factor of 3 had been estimated to approximate to the 95th percentile dose rate. In one case study application, the conservative dose rate output by Tier 2 was lower than the 95th percentile value estimated in Tier 3. However, it was noted that the deliverable also expressed some reservations with regard to the data used to derive probabilistic inputs for Tier 3 (which were derived by visual interpretation of a contour map).

2.7 Application of R&D 128 to Natura 2000 sites (D. Copplestone)

The question was asked as to what the Environment Agency would do if the threshold (of 40 µGy h^{-1}) is estimated to be exceeded. It was answered that in this case something (a regulatory action) would have to be done. It was then asked if this was in the public domain? The process that is being followed has been documented and agreed with Natural England (formerly English Nature) and has been publicised in conference presentations etc. where the overall approach to be and the derivation of the 40 µGy h^{-1} threshold has been described.

It was asked if all 'feature species' were legally protected. It was explained that they are, although there are some exceptions (e.g. some species of duck can be shot at certain times of the year).

An explanation of the derivation of dose conversion coefficient (DCC) values for a new organism was requested. These are derived from DCC:area/volume relationships fitted to the default geometries and that this was thought to introduce an uncertainty of approximately 10 %.

The question of what the estimated dose rate was for – the most exposed individual? – was asked. It was explained that some dispersion modelling is taken into account and that the assessment is for 'somewhere' within the Natura 2000 site.

Information on the input values (media activity concentrations) was requested. It was explained that this was based on the permitted (i.e. the total allowable) discharge which can be much higher than actual discharges. But this is what could potentially be discharged and hence this is what has to be assessed.

In answer to the question, 'how do you deal with uncertainty levels in exposure and effect analyses?', it was explained that this is a screening approach, for which the dose rate benchmark corresponds to a threshold.

The opinion was expressed that the threshold value of 40 µGy h^{-1} was low for regulatory purposes and may 'create a major headache for the rest of the world'. There are few effects data for birds (the most abundant organism type in assessments of Natura 2000 sites) and effects are difficult to see even at levels much higher than 40 µGy h^{-1}.

An explanation of the 1 km and 50 km cut-off limits (for deciding if an assessment was required) from the point of discharge for atmospheric and aquatic releases was requested. The lower distance for atmospheric releases was justified on the basis that atmospheric releases may be dispersed in any direction. It was stated (by one of the attending experts) that doses from atmospheric stack release in the US were insignificant. Subsequent to the workshop it has been clarified that radiological assessments consider: all permitted release upstream from a Natura 2000 site; all 'nearby' permitted sites for terrestrial releases.

It was asked whether other pollutants were relevant to the Natura 2000 assessment. It was answered that some heavy metals were present. Expanding on this, it was explained that for the River Ribble whilst biomarker studies were showing an effects gradient from Springfields, it is likely that this is not due to ionising radiation. One participant stated that in Canada, mining companies have to conduct a biological effects monitoring programme, but that the results can be difficult to interpret. D. Copplestone answered that the Environment Agency would not recommend action based on biomarker results, as these are not adequately defined.

2.8 Radioprotection of the environment in France: IRSN current views and workplan (K. Beaugelin-Seiller)

The question was asked whether the terrestrial and aquatic CR values were derived from data specific to France. At the moment, CR and K_d values are those of ERICA, and take into consideration their statistical distribution.

It was asked if IRSN were developing kinetic models. They are not for environmental risk assessment, as they are concentrating on the comparative risks of chemicals and radionuclides, with a focus on uranium at mining sites. However, they already have kinetic models for radionuclide transfer in river (CASTEAUR) and terrestrial (ASTRAL) ecosystems

2.9 Development of a dynamic assessment model (J. Vives i Batlle)

It was asked if the environment is modelled as a compartment? In answer, it was explained that the model includes three compartments, one is the environment (medium), and the two other describe the organism (one for the slow component, one for the fast component). The input data are a list of chronological concentrations.

It was questioned as to why the radioactive decay products return to the environment? It was explained that this was predominantly to simplify things as this provides an easy mathematical solution to the modelling (of a sink compartment for daughter radionuclides) which has little affect on the final numbers predicted.

It was asked if the CR values used were known to be determined under with equilibrium conditions? It was answered that preference was given in the literature review to experimental results where the steady state was stated as being reached.

Based on the results shown, it was suggested that integration of the dynamic results would lead to similar results to those of the equilibrium approach. J. Vives i Batlle responded that it depends upon timescale and biological elimination rate.

One member of the group stated that time-dependent input data would not be available. J Vives i Batlle suggested that this kind of approach is especially relevant for accidental releases, but also pulsed routine releases (e.g. decommissioning batch discharges), and that monitoring or modelled input data should be available in these situations.

The use of chronic exposure derived benchmarks as the screening levels in such a model was questioned as was the appropriateness of laboratory derived CR values (because of likely differences in bioavailability (physio-chemical form) compared to environmental sources). J Vives i Batlle stated that both these issues were under consideration, although in his opinion previous studies by Westlakes had demonstrated that laboratory derived CRs were not incompatible with field data.

The application of any standard/trigger values derived for chronic exposure to dynamic model outputs was questioned.

The model files were made available to all workshop participants with the request that it should not be used for purposes other than familiarisation (i.e. not for assessments or production of outputs for publications). It is intended that an improved release version will be available from the Westlakes website.

2.10 Experience assessing routine liquid effluent discharges from a Research Reactor - stringing together available software (J. Ferris)

In response to the question 'what were the effects data for – marine or freshwater', it was stated that these were difficult to separate in the FRED database.

It was asked if the probabilistic assessment took into account the probability of an accident occurring? J. Ferris responded that it did not and that no programme (chemical or radiochemical) could consider this.

The comment was made that in Canada, the potential tritium contamination of drinking waters from sewage plant releases is of public concern regarding human health. However, J. Ferris stated that this was not an issue in Australia, as processed sewage water does not enter the drinking water supply.

2.11 Experiences of applying R&D128, the ERICA-Tool and RESRAD BIOTA (M. Wood)

In response to the statement that a factor of 10 deviation from the measured data was considered 'acceptable' by the BWG, one participant commented that an acceptable level of agreement was a factor of 2-3 preferably with a higher rather then lower prediction compared to the measured value. Another participant, however, noted that this would depend upon the pathway and parameter being considered and that natural variability can typically approach an order of magnitude or greater.

2.12 EMRAS Biota Working Group – main findings (N.A. Beresford)

The use of the mean values for comparative purposes was questioned. In response it was explained that the BWG were in the process of statistically evaluating the Perch Lake and Chernobyl scenario results, which had only become available in the last few weeks, in more detail.

It was asked if the DCC values included daughter products (such as ^{90}Y for ^{90}Sr). It was answered that they do, although the $T_{1/2}$ cut-off for inclusion varies between models.

It was asked if TLDs were placed in the environment at the Chernobyl study sites, as well as being attached to animals. The answer was that some were, with TLDs being placed 10 cm below soil surface, on the soil surface, 5cm above the soil surface and 1 m above the soil surface. Comparative results were available for TLDs in these positions 'as attached to the animals' and also encased in 2 cm of Perspex to exclude beta exposure (the difference was *circa* three-fold). It was also noted that the use of air-kerma measurements may give an estimate of external dose rate experienced in a given area.

During discussion of the comparative results of the different participating models, it was stated that the transfer parameters within R&D128 would be reviewed in light of the BWG results (and publication of databases, such as that in the ERICA-Tool, would occur).

A draft summary table, prepared for the BWG report, of available models/approaches was distributed (see Appendix 1).

2.13 ICRP – intentions and requirements (K. Higley)

It was commented that criticisms, such as 'you are not considering banana plants', was a consequence of the naming of reference animals and plants (as specific organisms).

3. Scenario Application

3.1 Introduction

Participants were divided into four groups and provided with the scenario description and instructions for application using the three models for environmental assessment which are readily available to any user: RESRAD-BIOTA, the ERICA-Tool and R&D128 (see descriptions below). Section 3.2 presents the scenario instructions as given to workshop participants. Each group had somebody with some familiarity with each of the models. Key documents associated with each approach were available if required. Templates to help record the model runs and with various questions to prompt discussion were provided (see Appendix 2) and one (expert) member of the group was nominated to report back to the workshop.

3.1.1 RESRAD-BIOTA

The RESRAD-BIOTA code (available from http://www.ead.anl.gov/resrad) was designed to be consistent with, and provide a tool for, implementing the graded (tiered) approach for biota dose assessment (USDOE, 2002). The code includes a kinetic-allometric approach (Higley et al., 2003) to estimate the transfer of radionuclides to animals. The internal and external DCCs are estimated using a Monte-Carlo transport code. The version of the code used for the scenario was 1.22 beta, a development update not currently available from the above web address. This version should not be used further without the consent of ANL.

3.1.2 ERICA-Tool

ERICA (Environmental Risk from Ionising Contaminants – Assessment and Management) was a European Commission 6th Framework project providing an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of ionising radiation (Beresford et al., 2007). One of the projects outputs was the ERICA-Tool which implements the tiered approach of the ERICA Integrated Assessment. Transfer from contaminated media to a range of terrestrial and aquatic reference organisms is estimated using CRs, predominantly derived from the literature. For dosimetry, reference organisms are defined as simple, three-dimensional phantoms, i.e. ellipsoids and cylinders, as model geometric equivalents of reference organisms according to average characteristics of mass and size. The approach considers a layer of non-active tissue, i.e. the outer layers of the skin and/or fur causing a shielding effect for the living organism. Monte-Carlo techniques are applied that include all relevant radiation transport processes. The ERICA software and associated documentation are available from http://wiki.ceh.ac.uk/x/swbbBg.

3.1.3 England & Wales Environment Agency R&D128

This model uses a similar approach to ERICA, although more limited sets of organisms and radionuclides are considered (Copplestone et al., 2001). DCCs are estimated using simple functions for energy deposition in a medium of unit density from point isotropic sources to represent the absorption of photons and electrons. Energy absorbed fraction functions are fitted separately for photons and electrons to provide a reliable interpolation between calculated values. These functions are then integrated numerically using a stochastic (Monte-Carlo) algorithm to calculate the absorbed fraction.

Guidance is provided on how to estimate CR values if they are missing for a given radionuclide-organism combination (Copplestone et al., 2003) (later adapted for use within the ERICA approach). The spreadsheet-based models, which this approach uses, are freely available from http://www.coger.org.uk/R&D128index.html. Note the Environment Agency use an in-house implementation of the parameters from these spreadsheets coupled with simple dispersion models (these are not currently available externally) and not the spreadsheets as used in this scenario (which are those freely available to third parties).

3.2 Scenario provided to PROTECT workshop participants

The following reproduces the scenario instructions as presented to the workshop participants. However, for ease of reading within the context of this report the tense has been altered.

The scenario was based loosely on examples of the habitats assessments that have been undertaken within England and Wales by the Environment Agency. The examples were however modified in order to allow participants of the PROTECT workshop, to explore various aspects as described below. Increasingly more information was provided as participants progressed through the different parts of the scenario. Participants were asked to consider and answer various questions as they reached them in the text. Some background information was provided first.

Participants ran through each part of the scenario in turn using the normal approach that they would take to undertake an assessment of the impact of ionising radiation on non-human species. So, for example, if an activity concentration was to be provided as an answer to a question, then this was only to be reported if the tool being used actually presents this data. In other words the objective was to test how the tools available can be used without the need for the tool developers to provide additional outputs. Another example here would be to decide and record how a participant might handle the fact that the assessment requires an evaluation of a radionuclide that is not provided as a default in the tool(s) being used.

At the end of each scenario, participants were asked to consider the management options available to them and to decide on the recommendations that they, as the assessor, would provide to the decision-maker, bearing in mind the need to deal fairly and proportionately with each permitted authorisation.

3.2.1 Background

Feature species

At the Natura 2000 site of interest, the species listed in Table 1 may be present. The assessment was to consider the impact on these species. Some additional life history data was also provided (see below).

The aim of the Natura 2000 habitats assessments is to demonstrate that the integrity of the site is not being impacted by exposure to environmental contaminants, including ionising radiation. Within England and Wales, the sites have been identified by conservation organisations on the basis of the species present, which may vary from one or two species of interest through to a diverse (and/or rich abundance of a) range of species. The species listed in Table 1 have been identified as being of particular importance within the European Community area for freshwater ecosystems and therefore, the presence of one or more of these species at a particular location may lead to it being defined as a Natura 2000 site. An assessor needs to consider how to demonstrate protection of the integrity of the site and may use the species identified (as in Table 1) as a means to achieve this.

Table 1. Species that may be present in a freshwater Natura 2000.

Amphibians	Great crested newt (*Triturus cristatus*), Natterjack toad (*Bufo calamita*)
Birds	Bewicks swan (*Cygnus colmbianus*), Oystercatcher (*Haematopus ostralegus*)
Fish	Atlantic salmon (*Salmo salar*), Bullhead (*Cottus gobia*)
Invertebrates	Desmoulins whorl snail (*Vertigo moulinsiana*), Southern damselfly (*Coenagrion mercuriale*)
Mammals	Otter (*Lutra lutra*)

The River Able (an example for this scenario)

The River Able is 160 km long and rises at 900m above sea level in the north east of England. It flows over open moorland, widening before flowing over an extensive plain bounded by hills to the south and north towards a heavily industrialised estuary, which has large areas reclaimed from salt marshes and mudflats. The river/estuary ends in a Bay.

Saline intrusion used to penetrate about 28 km from the estuary mouth, but the strength of the tidal currents was not sufficient to produce complete mixing over the full length of the estuary and the system was classified as partially stratified. A barrage has now been constructed and this has prevented the access of saline waters to the upper portion of the estuary, reducing the estuary to 18km in length and turning the upstream section into a freshwater river.

In the 1970s, the River Able was virtually dead because of pollution. However, significant progress has been made to bring the river back to life. Dissolved oxygen is now present throughout the river at all times of the year. The types and abundance of animals that live in the river are responding to the improved water quality, with salmon breeding in the river and other species, particularly benthic ones, present. Parts of the River Able are now designated as a Natura 2000 site containing a mix of the species listed in Table 1.

Radioactive substances released into the River Able

There are a number of facilities that discharge radioactive substances under authorisation from the Environment Agency into the River Able. Potential discharges of radioactivity to the river arise from a Nuclear Power Station, several hospitals and a number of local non-nuclear industries and research facilities that are authorised to hold and discharge radioactive materials. These discharges are made directly to the river (for the purposes of this scenario).

3.2.2 Scenario

Taking the role of an employee of a governmental authority, the workshop participants were asked to undertake a retrospective assessment concerning the environmental impact of discharges from a number of non-nuclear/nuclear facilities discharging directly into a river (River Able) upstream of a freshwater Natura 2000 site and to consider the species of interest that may be present at the site. Site information on the River Able was provided (Table 2).

The nature of the assessment is such that stakeholders need not be involved at this stage. The analysis is being conducted to establish whether effects in the environment might have occurred.

The annual permitted discharges of radionuclides from each of the non-nuclear/nuclear facilities identified as being upstream of the Natura 2000 site were provided (Table 3). This represents the maximum amount of authorised radioactivity that may be discharged in any one year. Participants were asked to review this information and answer the generic questions before entering data into their model. For application in the model runs, release data had been pre-converted to water concentrations that might be obtained at the Natura 2000 site using a simple modelling approach (Table 4). The data provided in Table 4 were suggested as the input to models (rather than running dispersion models). It was suggested that it might be useful to run models with the water concentration resulting from discharges from all sites and then the water concentration resulting from certain site(s).

Table 2. Characteristics of the River Able

Depth (m)	1
Width (m)	50
Flow rate (m^3/s)	10
Average distance to the receptor from source (m)	10000

For the first run of a model, participants were requested to use default parameters (for concentration factors, occupancy factors, weighting factors and other relevant parameters) and compare the outputs of the model to their 'normal' comparative value(s) (i.e. dose screening rate(s)). If they modified any of the default parameters in Tier 2 or 3 (if appropriate) they were asked to these changes along with the justification for the change.

When the scenario was subsequently run through one of the other models, it was suggested that the same weighting factors and dose rate screening levels were retained.

<u>Management decisions</u>

Participants were requested to consider what recommendations they, as the assessor, might make to a decision-maker to advise on one or more possible courses of action based on the outputs of the assessment (for example, does the assessment need to move to a more detailed assessment (e.g. a Tier 2 or 3-type assessment). In this part of the scenario, it participants were requested to consider the management actions that might be taken if a) permit #6 was for a hospital conducting necessary medical treatments b) if permit #6 was for a research facility undertaking a series of research uses of radioactivity where there were some alternative methods that no longer use radioactivity and c) that permit #6 was for a facility which operates well within its permitted levels and d) consider the situation where several of the facilities contribute significantly to the dose rate calculated.

Table 3. Annual permitted release to River Able (Bq/y).

	#1a	#1b	#2	#3	#4	#5	#6	#7	#8	#9	#10	Total release
Tritium (not OBT)					4.40E+11	4.40E+08	9.00E+11	3.00E+10				1.37E+12
Carbon-14									1.20E+09			1.20E+09
Phosphorus-32/33			5.60E+08				1.20E+10					1.26E+10
Cobalt-60						4.40E+08						4.40E+08
Technetium-99m		2.40E+11		3.60E+11			8.40E+11	3.60E+11		3.60E+11	3.60E+11	2.52E+12
Iodine-125									1.20E+09			1.20E+09
Iodine-131							9.60E+10				1.20E+10	1.08E+11
Caesium-137		5.00E+11	4.50E+07				3.00E+10			6.70E+10		5.97E+11
Thorium-234	6.00E+07						1.40E+14					1.40E+14
Uranium-alpha	4.50E+08						1.00E+11					1.00E+11
Plutonium-alpha							4.00E+10					4.00E+10
Other alpha	9.90E+11						3.00E+10			9.00E+08	4.40E+08	1.02E+12
Other beta/gamma ($t_{1/2}$ > 10 days)		6.00E+08	2.40E+09	8.40E+10	1.80E+12	4.40E+11	4.80E+12	3.60E+10		2.50E+10	1.20E+10	7.20E+12

Table 4. Radionuclide concentrations in River Able water (Bq/l) at the Natura 2000 site of interest.

	#1a	#1b	#2	#3	#4	#5	#6	#7	#8	#9	#10	Total Release
Tritium (not OBT)					1.40E-01	1.40E-04	2.86E-01	9.54E-03				4.36E-01
Carbon-14									3.58E-04			3.58E-04
Phosphorus-32/33			8.34E-05				1.79E-03					1.87E-03
Cobalt-60						1.58E-05						1.58E-05
Technetium-99m		1.17E-03		1.75E-03			4.09E-03	1.75E-03		1.75E-03	1.75E-03	1.23E-02
Iodine-125									3.00E-04			3.00E-04
Iodine-131							1.01E-02				1.26E-03	1.13E-02
Caesium-137		1.44E-01	1.29E-05				8.61E-03			1.92E-02		1.71E-01
Thorium-234	1.93E-07						4.51E-01					4.51E-01
Uranium-alpha	1.39E-04						3.09E-02					3.10E-02
Plutonium-alpha							2.84E-03					2.84E-03
Other alpha	3.06E-01						9.27E-03			2.78E-04	1.36E-04	3.16E-01
Other beta/gamma ($t_{1/2}$>10 days)		1.72E-04	6.89E-04	2.41E-02	5.17E-01	1.26E-01	1.38E+00	1.03E-02		7.18E-03	3.44E-03	2.07E+00

3.2.3 Additional information

If results indicated that the assessment should move to Tier 2 or 3 it was requested that participants used the available information/data supplied below.

Name	Dimensions (cm)	Weight (kg)	Area/volume ratio m^{-1}	Prey	Occupancy factors		
					Sediment	Sediment surface	Water
Great crested newt	10 x 4 x 4	1.3E-02	107.5	Insects, molluscs	0.1	0.6	0.3
Natterjack toad	8 x 4 x 4	1.1E-02	93.8	Algae, plants, zooplankton	0.1	0.6	0.3
Bewicks swan	30 x 6.8 x 6.8	5.8E+00	34.0	Plants	0	0.3	0.5
Oystercatcher	17 x 2.8 x 2.8	5.0E-01	86.5	Molluscs, worms	0	0.7	0.1
Atlantic salmon	15 x 11 x 7	5.0E-01	41.1	Crustacean, insects	0	0.1	0.9
Bullhead	10 x 5 x 5	4.0E-02	170.5	Crustacean, insects	0	0.9	0.1
Desmoulins whorl snail	2.5 x 1.2 x 0.6	1.5E-03	688.5	Plants	0	0.2	0.5
Southern damselfly	1.5 x 0.8 x 0.6	1.0E-03	1270.8	Crustacean, insects	0	0.7	0.3
Otter	20 x 11 x 8	6.0E-01	36.8	Birds, frogs, fish, mammals	0	0.5	0.5

Some of the permitted discharges were expressed in a manner which the available tools could not use as direct inputs. In these instances the advice below was presented.

Category	**Examples of radionuclides that may fall into the category**	**Use this radionuclide in the scenario***
Other alpha	Ra-223, Ra-224, Ra-226, Th-232, Th-230, Th-234 etc	Pu-239
Pu-alpha	Pu-238, Pu-239, Pu-240	Pu-239
U-alpha	U-238, U-235, U-234	U-238:U-234=1:1
Other beta/gamma ($t_{1/2}$ >10d)	Bi-210, Br-76, 77 & 82, Cd-109, C-14, Ca-45, Co-56, 57 & 58, In-111 etc	Cs-137

*so that all the tools use the same input parameters.

3.3 Feedback and Discussion

With the exception of Group 1 (who only applied RESRAD-BIOTA and the ERICA-Tool), the groups managed to apply all three models to the scenario. Whilst some documentation on each model was available and some of the approaches contain help functions, time restrictions meant that these were not always consulted and this should be taken into account when assessing some of the comments on functionality.

3.3.1 Group 1

RESRAD-BIOTA

Results

At Tier 1 the risk quotient (RQ) exceeded 1, with the implication that the assessment should be continued. The RQ was 1.65, with Cs-137 as the main contributor and riparian animal the limiting organism (*N.B. RESRAD-BIOTA screening dose rates are 40 µGy/h for terrestrial & riparian organisms and 400 µGy/h for aquatic organisms*).

No dispersion model was available (therefore, the water activity concentrations were used). However, within the RESRAD family of codes, RESRAD-OFFSITE might allow the assessor to estimate dispersion. The logic built into the programme pre-selected the types of animals to be assessed and it was not immediately apparent what these were.

RESRAD–BIOTA Tier 3 gave the flexibility to do a more detailed analysis with options for allometric scaling and changing BiVs (*i.e. CR values*) available. Prey species could not be modelled in the programme as additional species-specific information is required which was not provided in the scenario. In this study, the group worked with the riparian animal by editing various parameters. It was possible to parameterise for a Bewicks swan in terms of size (nearest geometry, geometry 3, being used), occupancy factors and other attributes. The BiV aaproach was selected for calculating internal dose rates and the default BiV values were used.

The reduction in RQ between Tiers 1 and 3 was a little difficult to understand. The RQ (of 0.67) was lower at Tier 3, but the reasons for this were difficult to interpret. The group suggested that it may have something to do with less time in contact with sediment and lower external DCCs.

Functionality

Small menus can be problematic. On a more general note (applied also to ERICA) selection of reds and greens for screen displays can make analyses difficult (e.g. if the user is colour-blind).

The list of default radionuclides is limited. There were also run-time errors on the first (*Norwegian*) computer used. Unit conversions were required between Bq/l and Bq/m^3 etc.; functionality allowing unit conversions to be made would be useful.

RESRAD-BIOTA is generally easy to use - information is typed in and the output is easily retrieved.

<u>ERICA-Tool</u>

Results

Initial analyses were undertaken using the discharge data, with only Tc-99m excluded. Unit conversions were again required (ERICA requires discharge information as Bq s^{-1}). Also it was slightly irritating that all data must be entered by hand with no simple "right-click and paste" functionality. The results from this run appeared strange with RQs in the order of 10^5 (*N.B. as a default ERICA uses a 10 µGy/h screening dose rate*). It should be noted that ERICA sums RQs for different limiting organisms in the derivation of the overall RQ (*this is explained in some detail, in the ERICA-Tool help*).

Water concentrations were entered at Tiers 1 and 2, providing much more 'reasonable results' (RQ in the order of 10^1 - 10^2). The important radionuclides were Th-234, Cs-137 and Pu-239. Thorium-234 was the most important contributor, pelagic fish having the lowest RQ (2.1) and insect larvae the highest (114). If the RESRAD-BIOTA screening dose rates were used, RQ values were still exceeded for some organisms.

Alpha radiation weighting factors were changed from the default value of 10 to 20 to allow comparison with RESRAD-BIOTA. Since there was only one reference bird, this was attributed the characteristics of an oystercatcher.

Default parameters

A check was made of the C-14 CR data. Whilst these appeared to generally make sense, it appeared strange that for a specific activity model, the CR values differed between organisms (*Note – whilst in terrestrial ecosystems the ERICA-Tool was parameterised using a specific activity approach, within the freshwater ecosystem CR values were obtained by literature review*). It was also suggested that the consideration of HTO only was potentially a serious omission of the ERICA approach for aquatic ecosystems. A check was also made of the CR used for U to insect larvae and this was found to correspond closely to the data used in Canada.

A comment was made that the screening level for ^{3}H was very low, meaning that every assessment dealing with sites with any considerable emissions of ^{3}H would 'fail' at Tier 1. For some radionuclides and pathways, the screening level may be overly conservative.

Functionality

Positive feedback that the screens are large, easy to read and it is possible to access the underlying database. The ability to annotate data entries was also viewed positively.

A benefit at Tier 2 was that the analyses could be limited by matching species identified as potential present (i.e. Table 1) to reference organisms. It was also possible to enter Tc-99m at this stage using the add isotope functionality. The use of the uncertainty factor seemed reasonable. The 'Edit Radioecological Parameters' screen was informative.

In defining occupancy factors, the water-surface categorisation helped.

It was necessary to re-enter input data at Tier 2, but this is necessary because maximum values are normally expected at Tier 1, whereas average values are suggested at Tier 2.

Management questions

In dealing with the various radionuclide categories (e.g. 'other alpha'), the group concluded that generally, one should look for the analogue with the highest DCC (CR might also be taken into account). Most of the other generic questions were considered to be high level policy questions. However, it was noted that ERICA often provides valuable background information in relation to the derivation of values. RESRAD-BIOTA is well referenced, but sometimes it was difficult to establish provenance.

When screening levels are exceeded, follow up programmes (FUPs from the Canadian experience) are often required. For example, in Canada, in the case of validation of models used in the assessment of U mines, there is a general reluctance to make measurements in the field. The opinion was expressed that screening levels are often used as an "excuse" to avoid more detailed mechanistically based studies.

3.3.2 Group 2

Results

Different radionuclides and organisms were identified as resulting in RQ values in excess of one by the different approaches:

- ERICA = insect larvae (^{234}Th)
- R&D128 = amphibian (^{239}Pu)
- RESRAD-BIOTA = riparian animals (^{137}Cs)

There were large differences in total dose rates between the models (*dose rates to the most exposed organism varied over two orders of magnitude*). When trying to identify the reason for differences, it was considered useful to compare the internal and external contributions to total dose (this is possible with ERICA and R&D 128, but not RESRAD-BIOTA).

In trying to understand these differences the group compared CR values. Whilst most CR values were similar (see Table 5 later) a notable exception was the greatly larger CR value for amphibian used in R&D128 (*N.B. as there was a lack of data for Th transfer to amphibians, R&D128 assumes the CR is equal to the* K_d *value*).

Functionality

Relevant to all models – unit conversions were required for data entries (e.g. Bq/m^3 to Bq/l etc.) and it would be useful to have simple conversion tools available (e.g. drop down boxes with units for input data).

ERICA-Tool

Water concentrations had to be input for each tier of the assessment (*see comment from Group 1 above*).

Water concentrations were reported as an output (whereas they are, in fact, an input) and the link to the effects database was not functioning (*N.B. this has been checked following the workshop and the link is working: it is possible that there was an issue with the wireless network connection in the meeting room*).

R&D128

Initiation was difficult – "didn't know how to start" (i.e. the F1 key was required to do anything in the tool). Not overly user-friendly for a new beginner but a few easy fixes would rectify these problems.

RESRAD-BIOTA

The various tick boxes are difficult to understand. Internal versus external dose rate breakdown is not available, therefore, understanding the results was more difficult. BiV units are not specified (*although was later found to be unitless*). Tc-99m, I-125, P-32/33 were not in the list of radionuclides which could be selected in RESRAD-BIOTA.

3.3.3 Group 3

Results

The following critical radionuclides and limiting organisms (i.e. those combinations predominantly causing RQs to exceed 1), were identified from runs with R&D128 and RESRAD-BIOTA:

- R&D128 – amphibian highest dose rate (1930 µGy h^{-1}) with Pu-239 dominating (crustacean had comparatively low dose rate of 5 µGy h^{-1})
- ERICA – crustacean highest dose rate (1650 µGy h^{-1}) with Th-234 dominating (amphibian had comparatively low dose rate of 5.4 µGy h^{-1} with Cs-137 contributing most)

Interpretation of these results was confusing - for amphibian there was a three orders of magnitude difference. The group identified that the DCCs for Th and Pu were similar in the two models and questioned if the DCCs were being implemented correctly. The group also identified a large difference between default Pu CR values for amphibians between the models.

RESRAD-BIOTA identified riparian animals as the limiting organism (68 µGy h^{-1}), with considerably different dose rates to the other two models being estimated. The comment was made that the riparian animal had the highest RQ value and not the aquatic animal, which appears unexpected, as the aquatic animal spends all its time in the freshwater environment (*it was explained in discussion that this is because the riparian animal uses a lower screening dose rate of 40 µGy h^{-1}, compared to 400 µGy h^{-1} for aquatic animal*).

In relation to the DCCs, the question was asked as to whether orientation is important: an ellipsoid geometry is defined, but the user is unsure whether this lies vertically or horizontally to the source.

Functionality

Usability of the tools:

- R&D128 – reasonable once the function of the F1 key was identified; nice menu which is quite intuitive (*N.B. this group contained a moderately experienced user of the R&D128 spreadsheets*).
- ERICA – leads the user nicely though the process.
- RESRAD-BIOTA – difficult to establish a feel for user-friendliness in 1 hour.

A copy and paste functionality was available in R&D128.

Within the ERICA-Tool it would be useful to have a 'pull-through' of CR values when creating a new organism, where the user would need to define what category the new organism falls under (e.g. fish, bird) and then pull through the appropriate CR values. At the minute, it is a long-winded process to add CR values for all radioisotopes for a user-defined organism.

3.3.4 Group 4

Water concentrations based on authorised releases were used as input data.

Results

Surprisingly, individual tools selected different radionuclides as being the most important. There was a problem in understanding why this is the case.

RESRAD-BIOTA

The analyses exceeded the screening levels at Tier 1.

Further analysis at Tier 2 identified Permit 6 as the largest contributor to dose rates and it was, therefore, decided that they would be the first permitted site to be requested to reduce discharges). At Tier 3 the Bewicks swan (a user-defined organism) fell below the screening level and the dose rate was dominated by Cs-137.

R&D128

The same sequence was applied as when applying RESRAD-BIOTA. Plutonium-239 completely dominated the estimated dose, most notably Pu doses to amphibian. The analyses "failed" at Tier 1, but "passed" at Tier 2 assuming a screening dose rate of 400 µGy h^{-1} (*N.B. the Environment Agency use a threshold value of 40 µGy* h^{-1}).

ERICA

Thorium-234 was found to be the predominant radioisotope contributing to exposure, and to a lesser extent Cs-137. Some changes were made to ERICA default values by altering the alpha radiation weighting factors from 10 to 20 to correspond with that applied in RESRAD-Biota, but this had no effect on the final outcome.

Functionality

In terms of a general impression of the tools used: ERICA was "pretty good", RESRAD-BIOTA had a reasonable usability and Tier 3 could be navigated; R&D128 was sufficiently flexible.

Nonetheless, ERICA combines all the positive aspects of the other tools and might be considered the most sophisticated and highly developed of the three tools tested ('Generation 3' as opposed to 'Generation 2').

3.3.5 Discussion

Whilst the four groups did not necessarily obtain exactly the same results during the workshop (dependent upon various user decisions) findings from the three models tested were comparable for each group. The notable differences in model predictions were:

- ERICA – highest dose rate (*circa* E3 µGy/h) predicted for insect larvae dominated by ^{234}Th
- R&D128 – highest dose rate (*circa* E3 µGy/h) predicted for amphibian dominated by ^{239}Pu
- RESRAD-BIOTA – ^{137}Cs was the only nuclide to result in a risk quotient (RQ) in excess of 1 (for riparian animal).

As noted above, the Environment Agency use their own version of the R&D128 spreadsheets (and not the version available to third parties that was used during the workshop). Results from the Environment Agency's implementation of R&D128 were presented during discussion. These showed a dose rate to crustacean of *circa* 1500 µGy h^{-1} predominantly due to ^{234}Th; this was in agreement with the results of the ERICA-Tool.

Further discussion of the results of the scenario at the workshop and follow-up actions for the PROTECT consortium can be found in Section 4.

3.4 Understanding the results of the Vienna PROTECT scenario

Subsequent to the workshop, the reasons for the different results from the three models have been investigated further. All three models were run inputting ^{234}Th, ^{137}Cs (including other beta/gamma) and ^{239}Pu (including other alpha) water concentrations only (as these had been the three nuclides resulting in RQs >1 in the three models). For the first run, all model parameters were left at their default values. As the critical organisms in R&D128 and ERICA were amphibian and insect larvae, respectively, predications were made in RESRAD-BIOTA for organisms of default geometries 2 (for insect larvae) and 3 (for amphibian). To compare with ERICA results for insect larvae, the small benthic crustacean organism results were reported for R&D128.

Table 5compares predicted dose rates from the three models together with a number of the default parameter values; note that DCC values are broadly comparable for the three models and hence are not presented (*N.B. during the workshop, it was wrongly suggested that DCC values for ^{234}Th varied considerably between the models; this has subsequently been shown to be incorrect and was probably the consequence of converting the parameters from all models to consistent units*). Results are in accordance with those of the various groups during the workshop.

The most apparent differences between the model predictions are the high predictions of ^{239}Pu dose rates to amphibians by R&D128 and high predictions of ^{234}Th dose rates to insect larvae by ERICA. Looking at the default parameter values listed in Table 5, the K_d value for Th used in ERICA and the

Pu CR value for amphibians used in R&D128 are both considerably higher than those used by the other two models. The amphibian Pu CR value used within R&D128 is a ‘guidance’ value and is actually the models default Pu K_d value. A number of the K_d values used in ERICA originate from draft materials for the update of the IAEA transfer parameters handbook (TRS364); this includes the Th K_d value. We are currently trying to obtain verification of these values.

Table 5. Default parameter values as used in the three models and results using these for the River Able scenario.

Parameter/output	ERICA	R&D128	RESRAD-BIOTA
Radiation weighting factors			
α	10	20	20
Low-β	3	3	1
K_d values (l/kg)			
Cs	$1.37x10^5$	$1x10^3$	$5x10^2$
Pu	$1.39x10^6$	$1x10^5$	$2x10^3$
Th	$1.84x10^7$	$1x10^4$	$6x10^4$
Insect larvae (ERICA) cf Small Benthic Crustacean (R&D128) cf Geometry 2 (RESRAD-BIOTA)			
Total dose rate (μGy/h)	3200	4.25	27.96
Cs Total dose rate (μGy/h)	116	1.32	6.83
Pu Total dose rate (μGy/h)	10.7	2.59	19.21
Th Total dose rate (μGy/h)	3070	0.32	1.90
CR Cs (Bq/kg:Bq/l)	10400	5230	22000
CR Pu (Bq/kg:Bq/l)	1100	137	1000
CR Th (Bq/kg:Bq/l)	100	100	80
Amphibian (ERICA and R&D128) cf Geometry 3 (RESRAD-BIOTA)			
Total dose rate (μGy/h)	5.35	1898	27.58
Cs Total dose rate (μGy/h)	3.13	4.16	7.46
Pu Total dose rate (μGy/h)	2.20	1892	19.21
Th Total dose rate (μGy/h)	0.03	2.22	0.89
CR Cs (Bq/kg:Bq/l)	9300	11000	22000
CR Pu (Bq/kg:Bq/l)	230	100000	1000
CR Th (Bq/kg:Bq/l)	110	10000	80

The models were subsequently rerun using the default K_d values from R&D128 and CR values from ERICA in all three models. The results of this second model run are presented in Table 6. Results for the two selected organisms for all three models are now broadly consistent when considering that no other default parameters (including weighting factors, occupancy factors, sediment moisture content all of which differ between the models) were amended.

Relevant screen shots from each model run are presented in Appendix 3.

The results of the application of the Environment Agency's implementation of the R&D128 spreadsheets (see section 3.3.5) will be further investigated.

Table 6. Results using these for the River Able scenario using R&D 128 K_ds with ERICA CRs (amended parameters are indicated in red) in all three models.

Parameter/output	ERICA	R&D128	RESRAD-BIOTA
Radiation weighting factors			
α	10	20	20
Low-β	3	3	1
K_d values (l/kg)			
Cs	$1x10^3$	$1x10^3$	$1x10^3$
Pu	$1x10^5$	$1x10^5$	$1x10^5$
Th	$1x10^4$	$1x10^4$	$1x10^4$
Insect larvae (ERICA) *cf* Small Benthic Crustacean (R&D128) *cf* Geometry 2 (RESRAD-BIOTA)			
Total dose rate (µGy/h)	15.3	23.6	25.0
Cs Total dose rate (µGy/h)	3.11	2.46	3.51
Pu Total dose rate (µGy/h)	10.5	20.8	21.2
Th Total dose rate (µGy/h)	1.68	0.33	0.33
CR Cs (Bq/kg:Bq/l)	10400	10400	10400
CR Pu (Bq/kg:Bq/l)	1100	1100	1100
CR Th (Bq/kg:Bq/l)	100	100	100
Amphibian (ERICA and R&D128) *cf* Geometry 3 (RESRAD-BIOTA)			
Total dose rate (µGy/h)	5.35	7.96	8.02
Cs Total dose rate (µGy/h)	3.13	3.54	3.44
Pu Total dose rate (µGy/h)	2.20	4.35	4.42
Th Total dose rate (µGy/h)	0.03	0.06	0.17
CR Cs (Bq/kg:Bq/l)	9300	9300	9300
CR Pu (Bq/kg:Bq/l)	230	230	230
CR Th (Bq/kg:Bq/l)	110	110	110

4. Discussion Session

Opening the discussion the importance of investigating the details of models (as demonstrated by the scenario application) was stressed.

Following on from the presentations (see Section 2) and scenario application, and bearing in mind the objectives of the PROTECT project, members of the PROTECT consortium suggested various areas for discussion.

4.1 Guidance

Guidance had been identified as lacking in some models during the discussion. After application of the three models to the scenario, participants were asked to consider 'what is needed and where'. Several suggestions were made

(1) A simple short summary to enable people to start to use the models in a more informed manner.

(2) "Hover" boxes were considered useful – as they provide concise information with 'on/off' functionality

(3) An expert system leading the user into the analyses using dialogue boxes to prompt users to do certain things. However, there were some reservations over this, primarily who would the user be? For regulators with little radioecological expertise it was suggested that maybe a 'black-box' approach is acceptable/desirable. However, for higher level assessments (e.g. Tier 3 within the ERICA-Tool) competence and knowledge was considered to be required. Therefore, there is a need to balance user friendliness with the possibilities for misuse.

(4) There was some discussion concerning whether an advanced option could be made available (e.g. only parts of the tool would be accessible to a non-expert user). However, the openness and the transparency of the complete tool, to all users, were thought to be important to retain.

(5) It was suggested that workshops could be held, which included a simple assessment of the assessors understanding and use of a model (potentially with certificates of competence being issued). The RESRAD team has designed web-based tutorials at the request of the US Nuclear Regulatory Commission for reviewing dose compliance in license termination plans. This could be considered for other tools.

(6) It was suggested that a manual of case studies was a useful aid to tool users.

4.2 Key players and other systems that should be consulted/considered by the PROTECT project

It was stated that there was an intention for PROTECT to consult a wider group (e.g. those attending the Paris ERICA workshop) with regard to their views on the models they are using.

A potential organisation that was identified as one which should be consulted was SENES (Canada).

The BCG (biological concentration guideline) calculator was stated as having been replaced by the RESRAD-BIOTA code. However, it was acknowledged that people may still user the BCG calculator.

There will be an ISTC meeting (of Russian groups) on environmental protection and possible interaction with PROTECT will be raised (by S. Fesenko).

It is possible that some models (e.g. ECOMOD) have a role to play if more sophisticated models are considered necessary. The potential role (and usability) of the known models being used/proposed for use in environmental assessments (see Appendix 1) will be evaluated during the PROTECT project. The output of this may be summarised as an expanded version of the draft table presented in Appendix 1 of this report (and consequently it may not be too onerous a task).

A Japanese group (NIRS) have requested that they present an approach under development at the January 2008 workshop.

It was suggested that users of chemical assessment models should be considered within PROTECT. The consortium expressed the opinion that dialogue between the groups was adequate (supported by the fact that the Environment Agency have expertise in both chemical and radiological assessments). Furthermore, the ERICA approach incorporated a certain number of the methodologies derived for chemical assessments.

4.3 Acceptable level of agreement between model predictions and observed data

Some of the presentations (e.g. BWG activities) noted that model predictions (predominantly of biota activity concentrations) were considered acceptable if they were within 1-order of magnitude of the observed data. However, this had been questioned in discussion (see Section 2.11) and the topic was reintroduced for further evaluation.

It was suggested that this depended upon the direction of disagreement: one-order of magnitude above may be acceptable, but one-order of magnitude below may not (reflecting the requirement for conservatism in most assessments). However, some participants held the opinion that closer agreement than a one-order of magnitude deviation between modelled and measured values was necessary. To illustrate this, an example was given of a ^{3}H facility in Canada. This had been licensed following the application of models to assess impact. However, validation information was missing. Models were not making sense, but with a one-order of magnitude conservatism built in no action was considered necessary. Following an initial period of model validation a simple spreadsheet error was identified. The result was an emission level some 10-fold over that previously estimated over a 15 year period. It was also pointed out, however, that the feasibility of predicting within less than an order of magnitude would be dependent upon what is being predicted and the natural variability surrounding this.

There was a general consensus that quality control was essential for these types of tool. There are procedures that could be adopted (AECL documents being cited as an example) for more rigorous quality control of the applied models. However, this can become very involved.

A case in point was made concerning the K_ds used for ^{3}H in RESRAD-BIOTA, the ERICA-Tool and R&D128, which vary over three-orders of magnitude in difference. It was suggested that a comparison of the basic model parameters would be useful.

Nick Beresford informed the participants that following on from the results of the scenario application, it had been decided to conduct a simple comparison of model predictions assuming 1 Bq per unit media using RESRAD-BIOTA, the ERICA-Tool and R&D128. This might be achieved by simply comparing estimated RQ values. Results will be reported at the January 2008 workshop, although there will be interaction with tool developers in the meantime if anomalies are identified. It was suggested that it would also be useful if PROTECT documents why different models use different default parameters.

In relation to K_ds, it was stated that the site-specificity of these values has led the recommendation that site-specific information is always used in the USA. The onus is placed on the user to provide justification of the values. The key parameters are identified and the user is made aware of the importance of obtaining the correct information for them.

The key values for the tools used here are K_d and CR values. It is possible that sensitivity and uncertainty analyses could be applied to investigate these further. In cases where insufficient site-specific values are available, probabilistic methods can be applied.

It was noted that we need to bear in mind what PROTECT has promised: the project will help to provide technical advice on where problems lie and where improvement could be made. Furthermore, it will identify fit for purpose models to help with the EUs Basic Safety Standard (if required).

4.4 Implication of the use of different screening limits

Acceptance criteria, screening levels and other types of limits need to be clearly defined. Care needs to be taken with respect to terminology and what the values actually mean. A question was raised about the setting of trigger levels and the acceptability of exceedence: is it acceptable to exceed the guidance levels in some cases and if so how often? It was noted that Paul Whitehouse (EA) has provided some information on this (*see outputs page of the PROTECT website*) following discussions during the Chester PROTECT workshop.

4.5 Tools – fit for purpose?

Following discussions over the course of the workshop it was suggested that fitness for purpose needs to consider both 'screening models' and more realistic assessments. It was noted that the initial priority for PROTECT will be to consider the screening models, especially given the results of the scenario application (which demonstrated very different results for screening level assessments). It was requested that the PROTECT consortium consider if they can demonstrate the "degree of conservatism" in the different screening models. For example, the ERICA-Tool uses a 95th percentile prediction to set environmental media concentration limits (analogous to RESRAD-BIOTA's BCG values): is this sufficiently documented and is it adequately or overly conservative? This may also include an evaluation of the ERICA-Tools uncertainty factor approach (used in Tier 2; see Section 2.6). There was a general agreement that information on conservatism within the tools was lacking.

At Tier 3, the assessment becomes more site-specific and more realistic. It was suggested that mechanistic models might be more applicable, in some cases, for Tier 3 assessments. Temporal and spatial variation may need to be considered to evaluate the implications of the result.

One approach to assessing the degree of conservatism (and its acceptability) may be to use case studies to address acceptability (of conservatism) (see below for discussion of potential scenarios).

In consideration of the fitness of purpose of models, from the most recent exercise, it is clear that certain parameters need to be checked (this will be achieved by the 1 Bq per unit media comparisons discussed above).

There was also a suggestion to use the ERICA-Tool defaults in RESRAD-BIOTA or *vice-versa* (in part this has been done subsequent to the workshop, see Section 3.4).

The point was that it is important to have user knowledge to identify whether models are behaving properly. It was considered impossible to "idiot-proof" any particular model.

There was consensus that transparency and detailed documentation was important; there is a requirement to be honest about the use of old or obsolete reference values.

4.6 Transparency

A question was raised concerning the ERICA-Tool 'edit radioecological parameters' screens: is there a tendency for people to analyse or to accept the defaults? It was suggested that the latter is the case.

4.7 Data gaps

An objective of PROTECT should be to identify the most important data gaps. This is important in view of the large sums of money resting on some assessments. In this respect the use of extrapolation methods was considered useful, e.g. using allometric relationships and uncertainty/safety factors. The opinion was expressed 'that industry is often aware of where problems lie'.

4.8 Potential scenarios

As the group had expressed the view that further scenario testing may be useful in evaluation they were asked to suggest potential scenarios.

There was a suggestion that equilibrium versus non-equilibrium situations should be considered (following on from the presentation of J. Vives-i-Batlle). However, a discussion ensued as to applicability. One view was that this was only really important under accident scenarios with the concomitant problem that short-lived radionuclides would predominant and validation data (on transfer, etc.) were not available. This was further supported by the view that in the immediate post-accident situation human protection would be the priority. However, some expressed the view that dynamic models had been applied to routine discharge situations and had been shown of value. This view was backed-up by US experience, where dynamic models were found more suitable for assessment of some facilities (*it was unclear if this comment was made with respect to human or biota assessment*).

It was also suggested that U mining may provide a useful scenario. It was questioned whether this was appropriate for a European project. However, uranium mining industries are present in a number of EU states and opening of new mines is being considered (e.g. in Sweden). The historical way to limit the impact of U mines (in Canada) has been to release into a large lake and allow for dilution or release into a smaller lake, considering this as a filter to be sacrificed (and compensated for elsewhere) and to focus on (controlling) effects beyond this impact zone. The new thinking involves a "canary" approach: release to wetlands, which acts as a filter, before release into the main watercourse. A spatially sophisticated analysis is required in these circumstances. It was suggested that data may be available from Kakadu (Australia). For Canada, there are data for water, sediment and fish but otherwise there are large data gaps. It was considered that a U mine scenario would not be of use to evaluate screening tools, but that the project should further evaluate the possible benefits of a U mine scenario.

A ^{3}H scenario was also suggested. Brenda Howard said she would discuss the suitability of any EMRAS ^{3}H working group scenarios. Nick Beresford noted that he had been approached by a Romanian group who wished to be involved in PROTECT. In response, he had suggested that they propose a scenario for their CANDU reactor site for consideration within PROTECT.

It was also suggested that Savannah River could provide a suitable scenario.

The question arose as to whether there would be major revision of the ERICA-Tool following these workshops. It was emphasised that PROTECT was not an advancement of ERICA and that all available models and tools would be given equal priority (*however, areas of the ERICA-Tool identified for improvement will be relayed to the group (led by NRPA) maintaining the ERICA outputs*).

4.9 ICRP developments

A request was made to the ICRP Committee 5 representative that potential interaction with PROTECT be raised at the next meeting scheduled for October 2007 in Berlin and any feedback be provided for the January 2008 PROTECT workshop.

4.10 Other discussion items

There was a brief discussion on effects on individuals versus populations. Recovery time was suggested as a potentially useful criterion: if the local population recovers within several generations, then it can be argued that the impact is not adverse (this is the case in Canada). However, there remains the problem of defining the ‘population’. In the UK, there is a movement to defining an unacceptable population level effect as a given percentage change (likely to be 5 %) in population numbers per year over a number of years. Ideally, a method might be derived whereby distributions can be overlain as in AQUARISK (see presentation by J. Ferris).

A question was also raised with regard to the treatment of background radiation. It was noted that the ERICA integrated assessment deals with an incremental dose rate above background.

In response to discussion, it was stated that there is no intention for PROTECT to provide clean-up criteria for contaminated land.

Brief consideration was given to hot particles (following J-J Cheng’s presentation and the discussion of DU particles). It was agreed that consideration of hot particles would require a different suite of transfer and dosimetric tools and incorporate an element to account for the probability of spatial occurrence of particles.

During the discussion session participants were made aware that PROTECT provided an opportunity to feed suggestions into the EURATOM FP6 project FUTURAE which is evaluating the feasibility of establishing a network of excellence in radioecology within FP7.

4.11 Actions for the PROTECT consortium

A number of actions for the PROTECT consortium have arisen from the workshop. These are:

- To compare the underlying parameters used in RESRAD-BIOTA, the ERICA-Tool and R&D128. To be achieve by a simple 1 Bq per unit media scenario.
- To try to document why different models use different default parameters.
- To investigate if PROTECT can provide a mechanism to establish the "degree of conservatism" in the models.
- To expand Appendix 1 to provide an evaluation of each model.
- To identify the most important data gaps.
- To evaluate further scenarios for application, including: U mine site; Savannah River, ^{3}H releases.

A number of these objectives will require the active collaboration of model developers if they are to be successfully achieved.

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Appendix 1 – Summary of Available Models

Adapted from DRAFT table for inclusion in the IAEA EMRAS Biota Working Group Report (due end 2007).

Model	**Short description**	**Documentation** (see reference list above)
ERICA-Tool	Tiered approach considering exposure of biota in freshwater, terrestrial and marine ecosystems. In Tier 1 input media activity concentrations are compared to environmental media concentration limits. Tiers 2 and 3 include default CR and DCC databases for radionuclides of 31 elements and 38 reference organisms. Further organism and radionuclides can be defined by the user. Tier 3 has probabilistic ability. The tool contains outputs from/links to an on-line radiation effects database.	The ERICA-Tool is freely available from: http://www.project.facilia.se/erica/download.html. The tool contains extensive on-line help and associated documentation for the ERICA Integrated Approach is available from: http://wiki.ceh.ac.uk/x/swbbBg. The approach will be further described in a forthcoming special issue of *J. Environ. Radioact*. (due July 2008).
FASSET	Documentation for the environmental assessment framework includes tabulated CR and DCC values for marine, freshwater and terrestrial reference organisms. NOTE – the FASSET framework has been superseded by the ERICA-Tool.	All documentation available from: http://wiki.ceh.ac.uk/x/QADnBg. Elements of the framework were described within a special issue of J. Radiol. Prot. (2004; volume 24, 4A).
EA R&D 128	The approach and associated spreadsheet tools have been developed primarily to assess compliance with the EC Habitats Directive in England & Wales. The tools cover three ecosystem types: coastal, freshwater and terrestrial. The approach uses 'reference organisms' to represent biota and covers 16 and 18 radionuclides in aquatic/terrestrial ecosystems respectively. The tool uses an equilibrium based approach and default databases	Reports describing the approach are: Copplestone et al. (2001) Copplestone et al. (2003) The latest version of the report is available from the publications section of the Environment Agency's website (www.environment-agency.gov.uk) but this does not include the spreadsheet tools for those please visit http://www.coger.org.uk/R&D128index.html).

	contain parameters for concentration ratios for each reference organism geometry/radionuclide (obtained using guidance where there are gaps in the literature), weighting factors, occupancy factors and dose conversion coefficients (DCCs). DCCs are estimated using energy absorbed fraction functions calculated separately for photons and electrons. Organisms are defined as three-axis ellipsoids, assuming uniform distribution of internally incorporated radionuclides. The tools and guidance have been, and continue to be used by the Environment Agency to assess the impact of authorised discharges of radioactive substances to Natura 2000 sites in England and Wales in a regulatory context (i.e. if/when predicted doses exceed certain screening levels, regulatory action is required).	The dosimetric components are also discussed in Vives i Batlle et al. (2004).
CASTEAUR	Calculation tool for a dynamic assessment of spatio-temporal distribution of the radionuclide concentrations in the main abiotic and biotic components of the rivers, taking into account hydrography, hydraulic, sedimentary aspects, ecological functioning (trophic chain) and radioecology. Used for both routine and accidental discharges, with default parameterization for ^{110m}Ag, ^{241}Am, ^{58}Co, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{54}Mn, ^{103}Ru and ^{106}Ru.	Information: casteaur@irsn.fr Boyer et al. (2005). Duchesne et al. (2003). Beaugelin-Seiller et al. (2002).
EDEN	Calculation tool based on an intermediate solution between full Monte Carlo calculation and analytical empirical equations, to evaluate the energy dose rate	Free access on request at eden@irsn.fr / User license for dispersion traceability Beaugelin-Seiller et al.(2006).

	(expressed as a Dose Conversion Coefficient, DCC) delivered to non-human species exposed to any radionuclide present in the environment or internalised, for numerous user-defined configurations (any organism, any radionuclide (alpha, beta and gamma radiation) and from internal or external exposure).	Beaugelin-Seiller (2006a;b).
CARREN	Screening calculation tool (Excel file) to assess the ecological risk due to the occurrence or releases of radioactive substances in the environment, in relation with French NPPs. Three ecosystems (freshwater, terrestrial and marine) under consideration, for two exposure conditions (chronic -associated with routine releases, acute -in correspondence with minor accidents). Inputs are radionuclide concentrations in water, air and/or sediment/soil. Outputs are risk index per medium. Weighted and unweighted DCCs (calculated with EDEN) available, and selection of the dosimetric benchmark (default or customized value)	For information email: karine.beaugelin@irsn.fr Approach developed in collaboration with the French operator EdF, tool appraisal in progress. No documentation available at the moment
AECL approach	Where possible, site-specific CR values are used to estimate activity concentrations in receptor biota. If this is not possible, CRs from the Canadian literature and international reviews are used in combination with allometric approaches from RESRAD-BIOTA. For screening purposes, hyper-conservative internal and external DCCs, which are not corrected for organism size, are applied. For more realistic assessments (and the BWG exercises), DCCs from Blaylock et al.	

	(1993), FASSET or RESRAD-BIOTA are used.	
LIETDOS-BIO	LIETDOS-BIO for Environmental Protection is being developed to address contamination issues associated with nuclear power production in Lithuania. The code is designed to be consistent with MCNPX, a commonly used general purpose Monte-Carlo radiation transport model. An in-built method for describing phantoms allows exposure to be calculated for organisms of any size or form. The uncertainty in model parameter values is determined by a statistical approach. LIETDOS-BIO uses site-specific, and more realistic, terrestrial and aquatic CR and K_d values (when available) and takes into consideration their statistical distribution. The probability distributions assigned to all parameters are propagated to obtain the evaluation endpoint.	The LIETDOS-BIO approach is still under development. Calibration has been performed by participating in the IAEA EMRAS project. The LIETDOS-BIO dose rate evaluation model was used for the Ignalina NPP cooling pond Druksiai Lake hydrophytes exposure evaluation. Some results of these investigations are described in Nedveckaite et al. *(in-press)*.
SUJB approach	The model is used to carry out environmental impact assessments of nuclear facilities. The approach for estimating absorbed DCCs uses derived dose rate formulas as published elsewhere. Selected categories of organisms are represented by ellipsoid geometries of stated dimensions.	IAEA Technical Report Series No.190 and No. 332. Kimmel & Maschkovich (1972). The approach is further described in BWG documents.
RESRAD-BIOTA	A computer code that implements the U.S. Department of Energy's (DOE's) graded approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. Its database contains 45 radionuclides, four reference organisms, and eight reference geometries.	RESRAD-BIOTA is freely available and can be downloaded from the RESRAD Web site (http://web.ead.anl.gov/resrad) or the U.S. Department of Energy Biota Dose Assessment Committee Web site (http://homer.ornl.gov/nuclearsafety/oepa/public/bdac) after

	"New organism wizard" provides step by step instructions on creating new organisms for consideration, which can be linked to organisms of lower trophic levels as food sources, thereby enabling the establishment of food web relationships. Text reports and graphic charts are generated and can be exported. Sensitivity analyses on input parameters can also be automatically conducted.	completing the on-line registration. Related documents on the methodology and operation of the code (user's guide) are also available from the web sites.
EPIC-DOSES-3D	Research tool that allows doses from external (β particles, photons) and internal exposure (α, β particles, photons) in biological objects of any (user-defined) size and form to be calculated. Doses can be calculated for any radionuclide, although in the present version of the program an initial data set for 42 radionuclides is used. The software has been used to derive dose conversion coefficients in the EPIC project (Golikov & Brown, 2003) and is under further development.	A trial version of the tool is freely available on request from the developer – The Institute of Radiation Hygiene, Russia (contact xxx) Golikov & Brown (2003).
FASTer (lite)	FASTer (lite) is a multi-compartmental model that can be used to simulate transfer through a simple terrestrial food-chain. The rate of change of the radionuclide inventory in compartments is described with a linear differential equation. The activity concentrations of dietary components are characterized using ERICA concentration ratios. Intakes of radionuclides are simulated using (i) allometrically derived ingestion rates, (ii) radionuclide-dependent assimilation efficiencies and	The model is not openly available as a completed software code but its configuration within appropriate simulation software (e.g. Model Maker, ECOLEGO) is a straight-forward process. The original model description can be found in: Brown et al. (2003a).

	(iii) assumptions concerning dietary composition. Biological half-lives are defined using allometric relationships. An earlier version of the model was used to derive numerous CR values in the FASSET project and a few values used as default in ERICA.	
EPIC – "Environmental Protection from Ionising Contaminants in the Arctic"	Within the EPIC project a methodology was developed specifically for Arctic ecosystems. This was achieved by derivation of dose limits for different biota. The project involved (i) collation of information relating to the environmental transfer and fate of selected radionuclides through aquatic and terrestrial ecosystems in the Arctic; (ii) identification of reference Arctic biota that can be used to evaluate potential dose rates to biota in different terrestrial, freshwater and marine environments; (iii) modeling of the uptake of a suite of radionuclides to reference Arctic biota; (iv) development of a reference set of dose models for reference Arctic biota; (v) compilation of data on dose-effects relationships and assessments of potential radiological consequences for reference Arctic biota; (vi) and integration of assessments of the environmental impact from radioactive contamination with those for other contaminants.	Brown et al. (2003b). EPIC reports are available on the following link: http://wiki.ceh.ac.uk/x/fwDnBg
DosDiMEco	In this model soil-plant transfer factors (dry/dry basis) and CR values are use for calculation of the concentration in invertebrates, fish and plankton. For terrestrial mammal and bird species concentrations are	The model is being developed through interaction in the EMRAS Biota WG. Consequently no published documentation on this model is yet available. For specific information contact the modellers at XXXX@sckcen.be (to

	calculated from the intake rate (using an allometric relation between body mass and intake rate), fractional gastrointestinal radionuclide absorption and retention inside the animal body. By using a DCC, derived by using a build-up factor corrected point Kernel technique and the Beth-Bloch equation, the internal and external dose can be calculated.	be specified)
LAKECO	LAKECO is a dynamic uptake model, developed by NRG Arnhem, the Netherlands from 1992-1999. It takes into account the propagation of radionuclides throughout the entire food web. It was validated within the IAEA coordinated VAMP project (1992-1995), and tested within BIOMOVS II (1995). Its aim is to have a generally applicable ecological model for lakes ecosystems with a minimum amount of input parameters. The predictive power is high due to the use of subroutines which uses environmental parameters as input, so calibration is therefore not needed. For the uptake of radionuclides it uses the target-tissue approach instead of nuclide bases approach, limiting the amount of input parameters. LAKECO is part of the DSS system RODOS, and MOIRA. Variants are also applied for the marine environment (BURN98, POSEIDON - R). A release exists to calculate the tritium uptake in biota as well including OBT.	BIOMOVS 1996. VAMP Lake Report (2000) LAKECO is available as a stand-alone tool, and as part of the hydrological module of RODOS, RODOS-HDM.
ECOMOD	A freshwater transfer model which uses stable element concentrations in water for some radionuclides.	Elements of the model are described in Sazykina (2000); Kryshev (2000 a;b) and Kryshev & Ryabov (2000).

	Within BWG, have applied DCCs derived from literature.	
D-Max	Screening model for assessing exposure of biota in freshwater, terrestrial and marine ecosystems. Calculates maximum possible dose to any organism or tissue in the given ecosystem. No assumptions concerning species of organism, geometry, or behaviour are required for this screening approach.	Approach is presented in: Smith (2005)

Appendix 2 – Results Templates Distributed For The Workshop Scenario Application

Questions for each model

1	Which model (and version no/date of release) are you using?	
2	Your name(s) (for follow up questions only)	
3	Can you apply the model to all the radionuclides listed in Table 2?	Yes/No
4	If no, please a) list which radionuclides you can not assess directly and b) how have you/do you plan to assess the radionuclide(s) listed?	
6	How have you considered all the species listed in Table 1 within the assessment? If no, why not?	
7	Are there any parameters that you do not have information for that are required for the model to run?	
8	Does the model output indicate that further work is required/screening level exceeded? Please indicate the species/nuclide(s) that are causing the screening level to be exceeded	

Generic Questions (model independent)

Your names (for follow up questions only)	
Could you/have you dealt with the 'other' radionuclide categories (for example "other alpha" or "other beta/gamma")? Please expand how this has been dealt with.	
What are you using to compare (e.g. screening level) the output of the model (list model as this may depend upon the model for the group you are assigned to) to? What is the science that underpins the value(s) that you are using as a screening level? Would you modify the screening value if circumstances change – what circumstances might these be?	
If the screening level identified above was to be exceeded, what kind of work would you recommend is needed to continue the assessment?	

Management Options

Permit #6 as a hospital

Permit #6 as a research facility

Permit #6 as a normal facility operating well within its permitted discharges

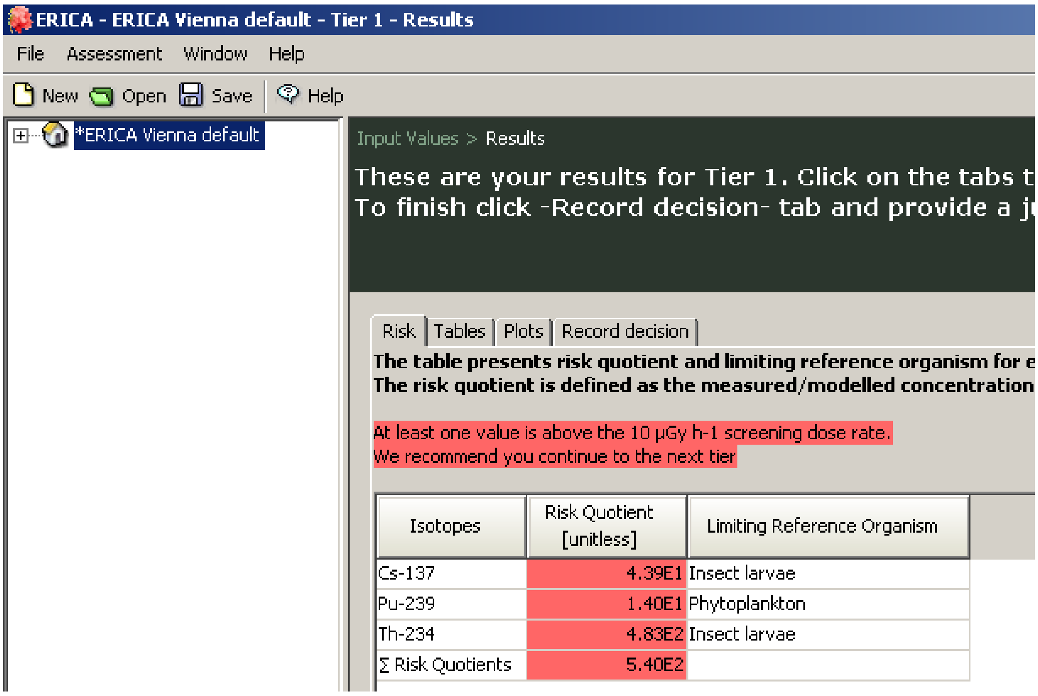
Multiple permits contribute to the overall calculated dose

Appendix 3 - Screen Shots

Default Runs

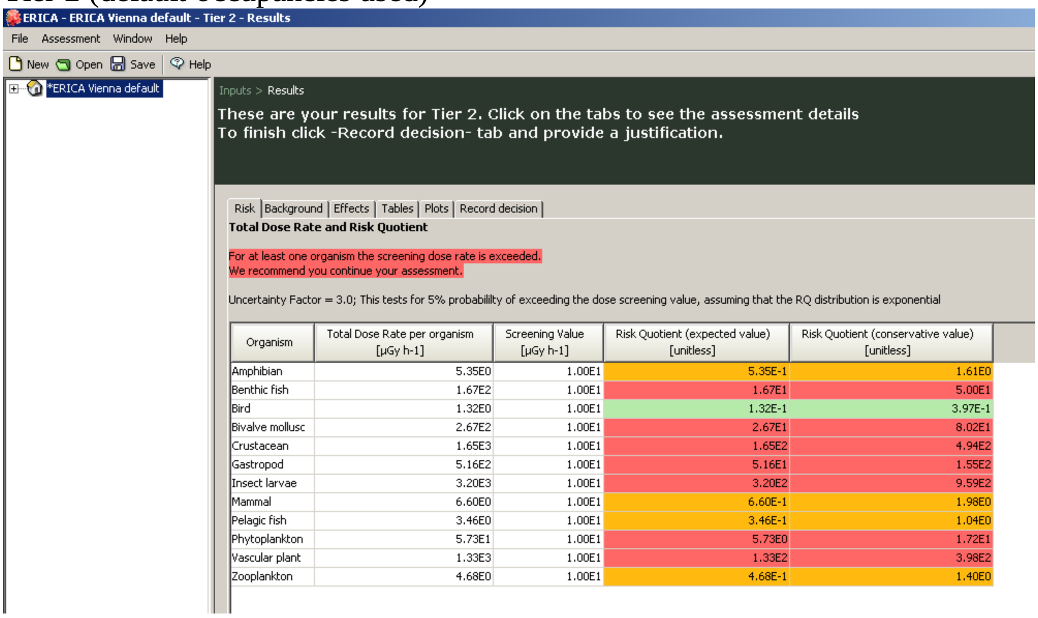
ERICA

Tier 1

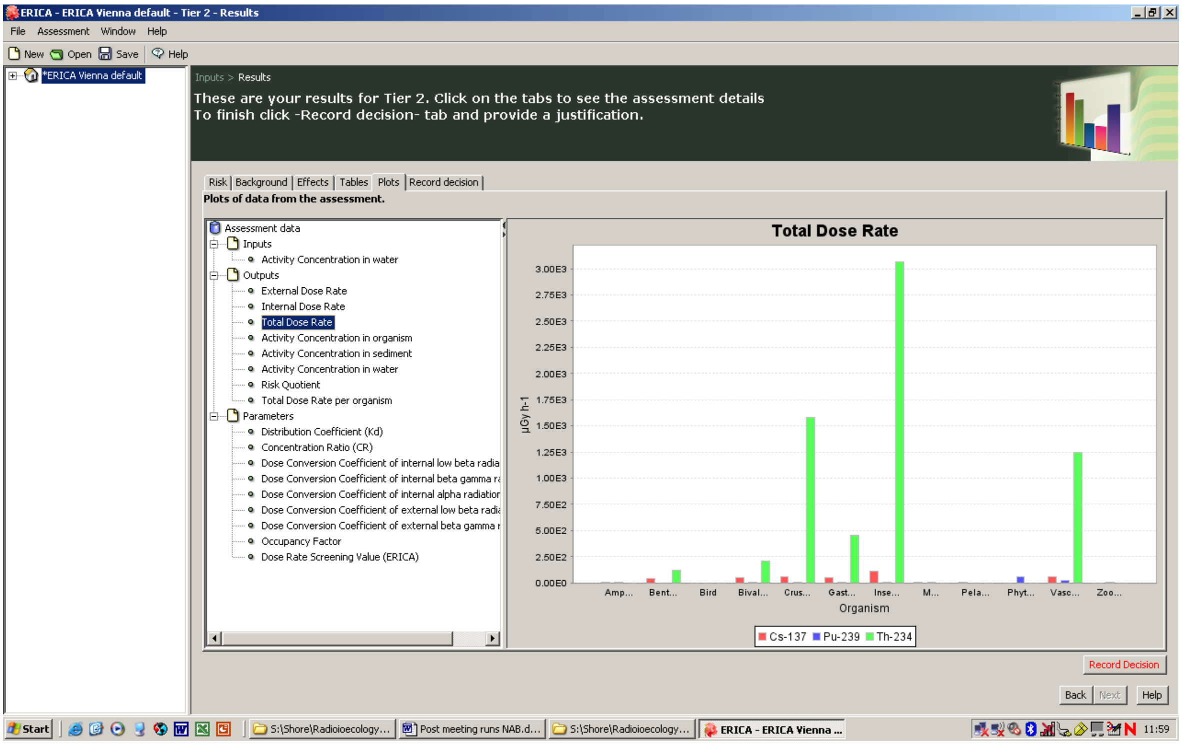


Isotopes	Risk Quotient [unitless]	Limiting Reference Organism
Cs-137	4.39E1	Insect larvae
Pu-239	1.40E1	Phytoplankton
Th-234	4.83E2	Insect larvae
Σ Risk Quotients	5.40E2	

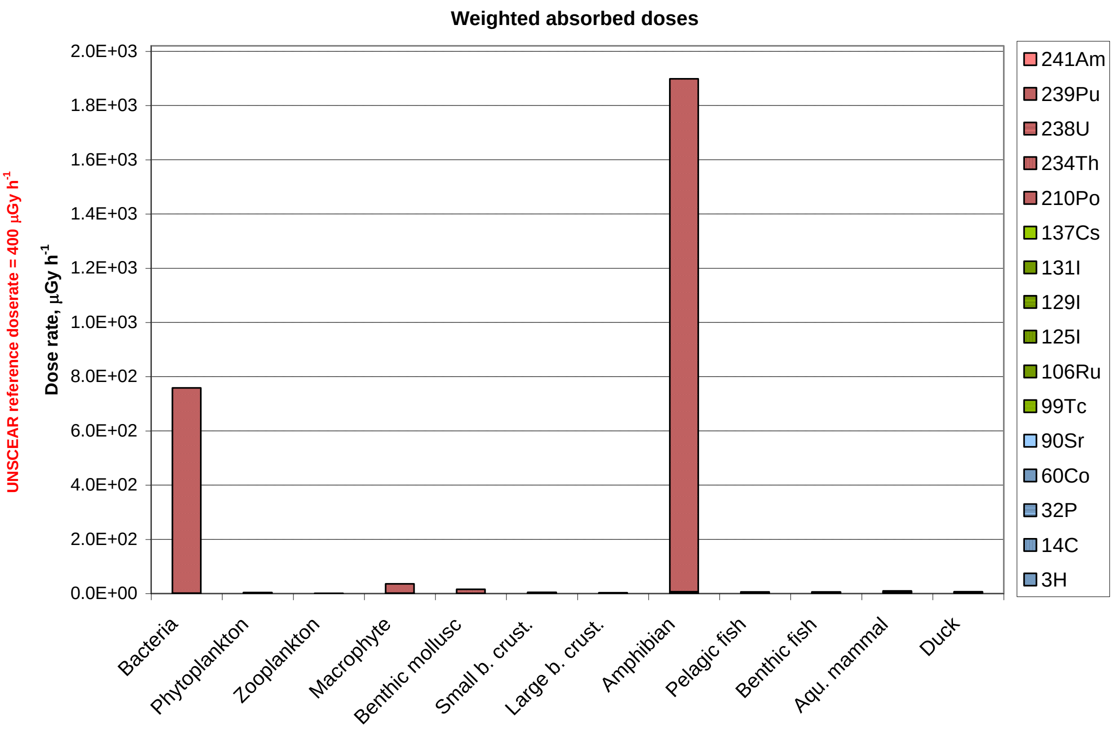
Tier 2 (default occupancies used)



Organism	Total Dose Rate per organism [µGy h-1]	Screening Value [µGy h-1]	Risk Quotient (expected value) [unitless]	Risk Quotient (conservative value) [unitless]
Amphibian	5.35E0	1.00E1	5.35E-1	1.61E0
Benthic fish	1.67E2	1.00E1	1.67E1	5.00E1
Bird	1.32E0	1.00E1	1.32E-1	3.97E-1
Bivalve mollusc	2.67E2	1.00E1	2.67E1	8.02E1
Crustacean	1.65E3	1.00E1	1.65E2	4.94E2
Gastropod	5.16E2	1.00E1	5.16E1	1.55E2
Insect larvae	3.20E3	1.00E1	3.20E2	9.59E2
Mammal	6.60E0	1.00E1	6.60E-1	1.98E0
Pelagic fish	3.46E0	1.00E1	3.46E-1	1.04E0
Phytoplankton	5.73E1	1.00E1	5.73E0	1.72E1
Vascular plant	1.33E3	1.00E1	1.33E2	3.98E2
Zooplankton	4.68E0	1.00E1	4.68E-1	1.40E0

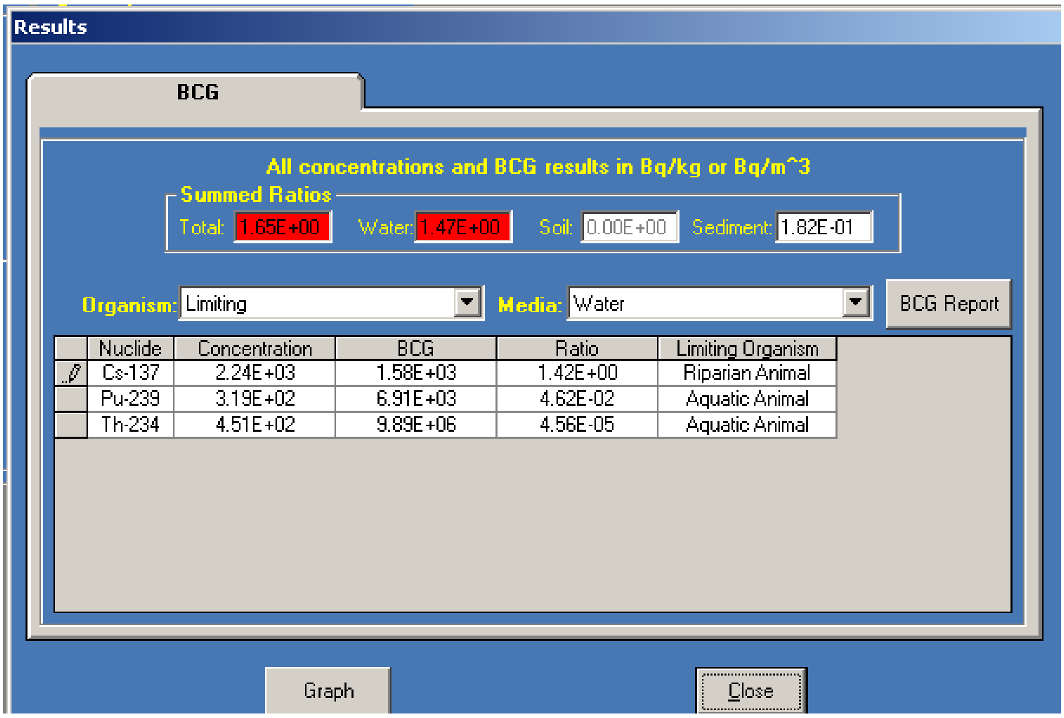

ERICA - ERICA Vienna default - Tier 2 - Results
File Assessment Window Help
New Open Save Help
*ERICA Vienna default
Inputs > Results
These are your results for Tier 2. Click on the tabs to see the assessment details
To finish click -Record decision- tab and provide a justification.
Risk Background Effects Tables Plots Record decision
Plots of data from the assessment.
Assessment data
Inputs
Activity Concentration in water
Outputs
External Dose Rate
Internal Dose Rate
Total Dose Rate
Activity Concentration in organism
Activity Concentration in sediment
Activity Concentration in water
Risk Quotient
Total Dose Rate per organism
Parameters
Distribution Coefficient (Kd)
Concentration Ratio (CR)
Occupancy Factor
Dose Rate Screening Value (ERICA)
Total Dose Rate
µGy h-1
Organism
Cs-137 Pu-239 Th-234
Record Decision
Back Next Help
Start
11:59

R&D 128


Weighted absorbed doses
UNSCEAR reference doserate = 400 µGy h-1
Dose rate, µGy h-1
2.0E+03
1.8E+03
1.6E+03
1.4E+03
1.2E+03
1.0E+03
8.0E+02
6.0E+02
4.0E+02
2.0E+02
0.0E+00
Bacteria
Phytoplankton
Zooplankton
Macrophyte
Benthic mollusc
Small b. crust.
Large b. crust.
Amphibian
Pelagic fish
Benthic fish
Aqu. mammal
Duck
241Am
239Pu
238U
234Th
210Po
137Cs
131I
129I
125I
106Ru
99Tc
90Sr
60Co
32P
14C
3H

RESRAD

Tier 1



Tier 3

Insect larvae = geometry 2; default BiV
Amphibian = geometry 3; default BiV

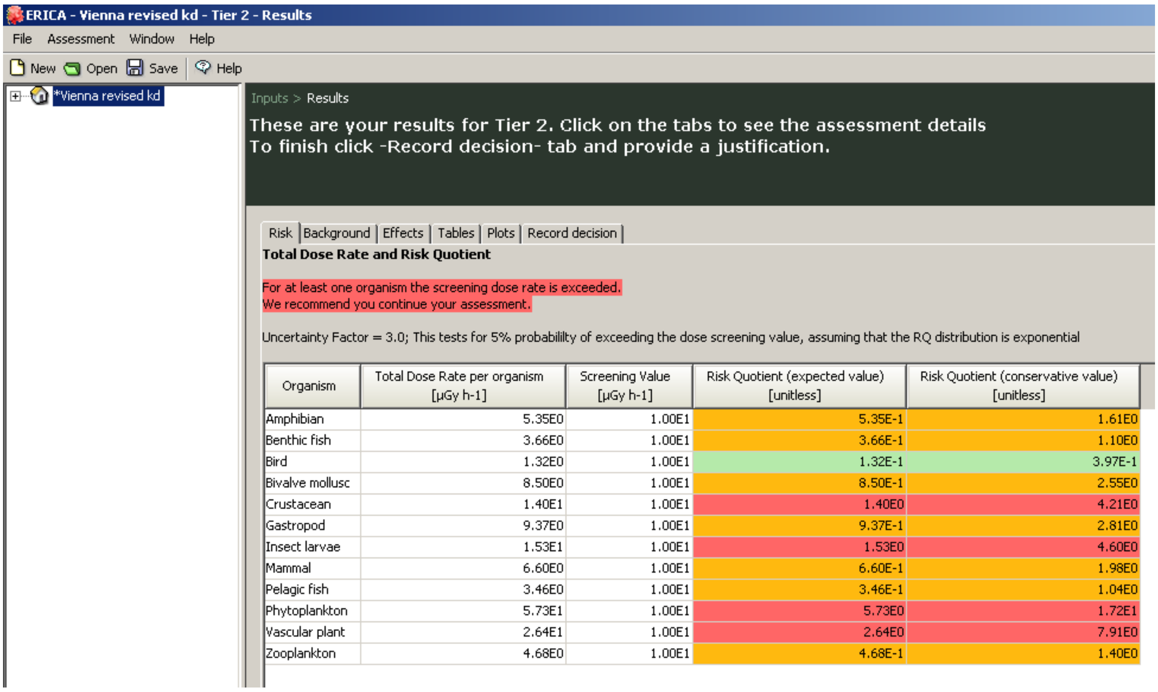
Insect larvae					
Nuclide	**Water**	**Soil**	**Sediment**	**Tissue**	**Summed**
Cs-137	1.60E-04	0.00E+00	4.46E-06	0.00E+00	1.64E-04
Pu-239	4.61E-04	0.00E+00	1.78E-09	0.00E+00	4.61E-04
Th-234	3.31E-07	0.00E+00	4.51E-05	0.00E+00	4.55E-05
Summed	6.21E-04	0.00E+00	4.96E-05	0.00E+00	6.71E-04

Amphibian					
Nuclide	**Water**	**Soil**	**Sediment**	**Tissue**	**Summed**
Cs-137	1.75E-04	0.00E+00	4.29E-06	0.00E+00	1.79E-04
Pu-239	4.61E-04	0.00E+00	1.02E-09	0.00E+00	4.61E-04
Th-234	3.95E-07	0.00E+00	2.09E-05	0.00E+00	2.13E-05
Summed	6.37E-04	0.00E+00	2.52E-05	0.00E+00	6.62E-04

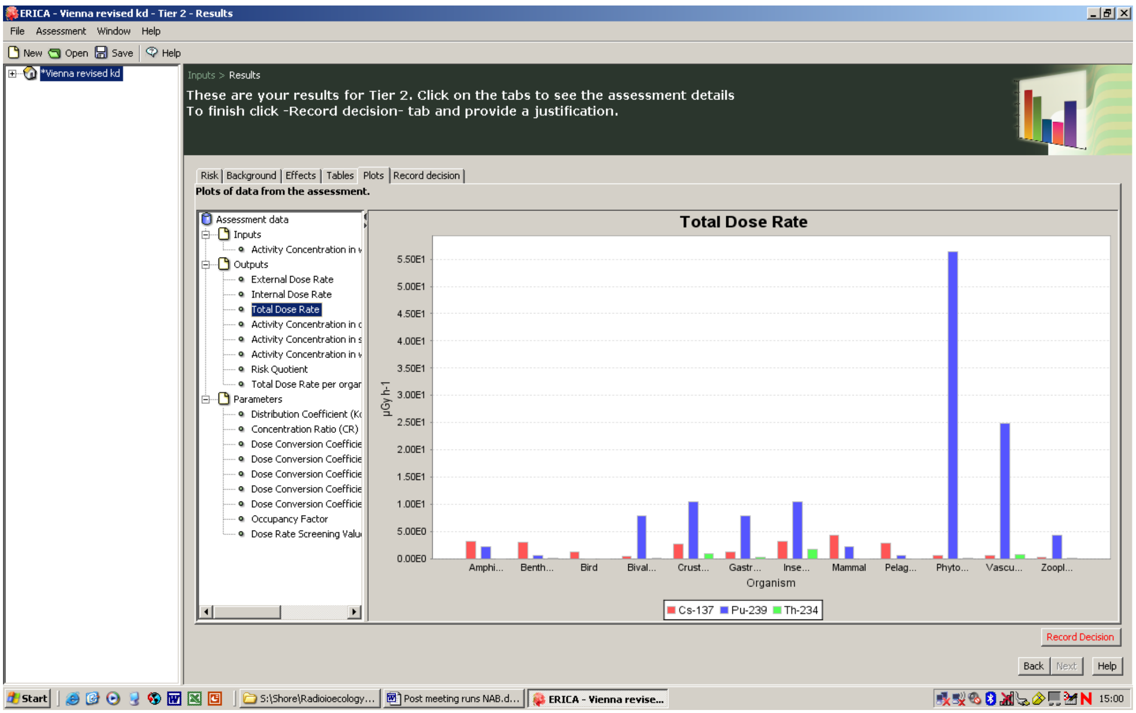
Rerun With ERICA CRs and R&D128 K_ds

ERICA

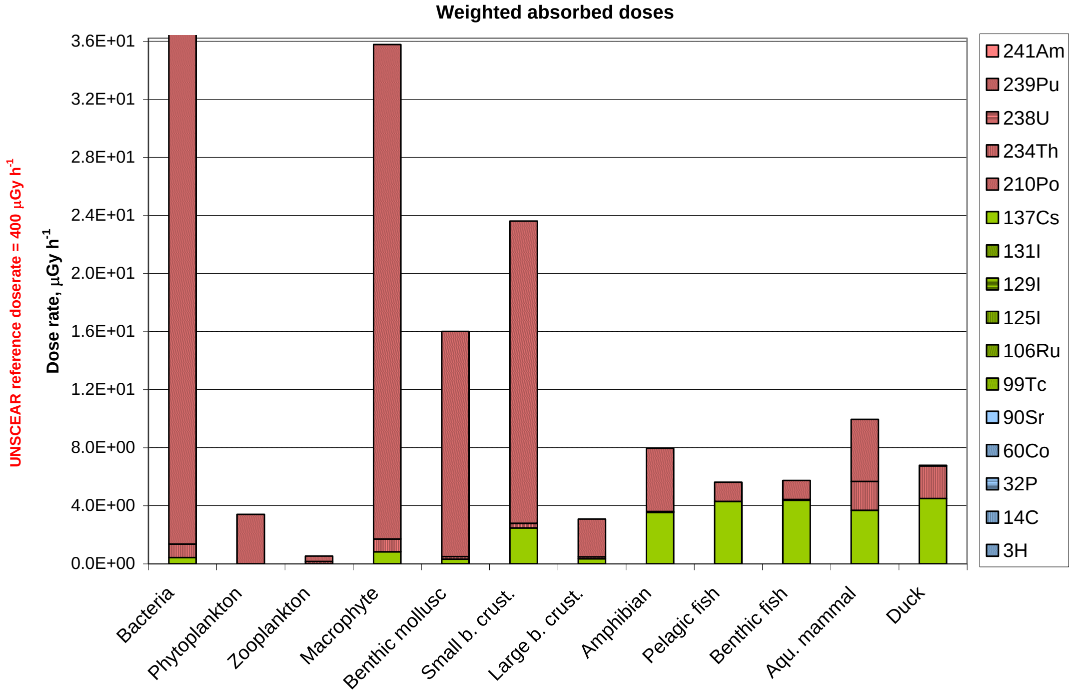
Tier 2



Organism	Total Dose Rate per organism [µGy h-1]	Screening Value [µGy h-1]	Risk Quotient (expected value) [unitless]	Risk Quotient (conservative value) [unitless]
Amphibian	5.35E0	1.00E1	5.35E-1	1.61E0
Benthic fish	3.66E0	1.00E1	3.66E-1	1.10E0
Bird	1.32E0	1.00E1	1.32E-1	3.97E-1
Bivalve mollusc	8.50E0	1.00E1	8.50E-1	2.55E0
Crustacean	1.40E1	1.00E1	1.40E0	4.21E0
Gastropod	9.37E0	1.00E1	9.37E-1	2.81E0
Insect larvae	1.53E1	1.00E1	1.53E0	4.60E0
Mammal	6.60E0	1.00E1	6.60E-1	1.98E0
Pelagic fish	3.46E0	1.00E1	3.46E-1	1.04E0
Phytoplankton	5.73E1	1.00E1	5.73E0	1.72E1
Vascular plant	2.64E1	1.00E1	2.64E0	7.91E0
Zooplankton	4.68E0	1.00E1	4.68E-1	1.40E0



R&D128



RESRAD

Tier 3