

# Findings and recommendations from an international comparison of models and approaches for the estimation of radiological exposure to non-human biota

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## INTRODUCTION

Internationally, the ICRP and IAEA are addressing environmental protection as an element of their ongoing revision of recommendations and Basic Safety Standards respectively. Some countries already have requirements and guidelines for the protection of non-human biota. For instance, in England and Wales, the requirement to assess impacts affecting Natura 2000 sites (under the Conservation (Natural Habitats) Regulations 1994 the UK implementation of the EU Birds and Habitats Directives) has been interpreted to include ionising radiation. In the USA, biota protection guidelines and dose rates are contained in USDOE Orders 5400.5 and 450.1.

In response to these developments, a number of models and approaches have been developed specifically to estimate the exposure of non-human biota to ionising radiations. Some countries (e.g. Canada, England and Wales, and the USA) are now using these within their national regulatory frameworks for (existing and proposed) nuclear and other sites that may be releasing radioactivity to the environment. Software and/or documentation for some of these approaches are readily available and hence third parties are able to use them.

The *Biota Working Group* (BWG; <http://www-ns.iaea.org/projects/emras/emras-biota-wg.htm>) was formed by the IAEA as part of the Environmental Modelling for Radiation Safety (EMRAS) programme in 2004. The primary objective of the BWG, was: ‘to improve Member State’s capabilities for protection of the environment by comparing and validating models being used, or developed, for biota dose assessment (that may be used) as part of regulatory process of licensing and compliance monitoring of authorised releases of radionuclides’.

In total, 15 models and approaches have participated in the activities of the BWG. These encompass those being developed, and in some instances applied in a regulatory context, in the USA, Canada, France, Belgium, Russia, Lithuania, and the UK, as well as the outputs of recent EC EURATOM programmes. In this paper, we describe the findings and recommendations of the BWG.

## INTERCOMPARISON EXERCISES

The BWG has conducted two model-model comparisons to compare the basic components of the participating models (dose conversion coefficients (DCCs) and approaches to transfer) and two model-data comparisons utilising databases for aquatic (Perch Lake, Canada) and terrestrial (Chernobyl exclusion zone) ecosystems. The participating models included those available to any interested user (RESRAD-BIOTA, ERICA, EA R&D128 and FASSET (see [http://www.ceh.ac.uk/protect/pages/env\\_protect\\_radio.html](http://www.ceh.ac.uk/protect/pages/env_protect_radio.html) for links to documentation and/or software for these approaches)) and in-house models being used/developed by various BWG participants. Group members included modellers, regulators, industry and researchers.

In this paper, we concentrate on the main conclusions and recommendations arising from these exercises. Details of the exercises and results can be found elsewhere: Vives i Batlle et al. (2007) - comparison of dose coefficient; Beresford et al. (*submitted*) - comparison of transfer components; IAEA (*in-press*) - details of all the BWGs activities; Beresford et al. (*in-press*) - overview of early phases of the BWGs work.

## CONCLUSIONS

### **Dosimetry and transfer components of the models**

The exercise to compare predicted unweighted whole-body absorbed dose rates (reported as DCCs) for a selection of the proposed ICRP Reference Animal geometries demonstrated that all the 11 participating approaches generally estimated comparable internal dose rates even though different assumptions were made. The notable exception was as a consequence of different daughter products being included (e.g. one approach included  $^{234}\text{U}$  in the estimation of the DCC for  $^{238}\text{U}$ ). Variation was greater for the estimation of external dose rates, most notably for  $\alpha$ - and  $\beta$ -emitters. However, it is generally accepted that external exposure to biota by such emitters is of little radiological significance, due to their low range in matter.

The comparison of predicted activity concentrations in a range of freshwater and terrestrial biota by eight of the participating models, assuming 1 Bq per unit media, demonstrated considerably more variability than the comparison of unweighted dose estimates. For many radionuclide-reference organism combinations, variability in predictions covered three, or more, orders of magnitude. Predictions were often most variable for poorly studied organisms such as fish egg, bird egg, duck, amphibian and aquatic mammals. Some of the more extreme variability could be explained by the use of 'guidance' methodology to provide values by a number of approaches in the absence of data. However, in some cases this guidance methodology is intended to be conservative and in most instances it resulted in comparatively high (and hence conservative) predictions.

### **Scenario applications**

The two scenario applications allowed model predictions to be compared to measured whole-body activity concentration data for a range of freshwater and terrestrial biota. The majority of the models predicted activity concentrations in most organism types to within an order of magnitude of the observed data.

The results of the scenarios were largely in agreement with those of the earlier exercises to compare the dosimetry and transfer components of the models. The understanding of the different models gained in the early phases of the work aided interpretation of poor predictions and variability between the models.

The variability between the participating models in estimated dose rates could largely be explained by the variability in predicted whole-body activity concentrations. Surprisingly, there was less variability observed in the estimated total dose rates (typically less than an order of magnitude) than may have been anticipated from observed variation in predicted activity concentrations (typically at least three orders of magnitude). This was the consequence of given models under-estimating for one radionuclide whilst over-predicting for another for the same organism and hence balancing out the overall prediction of dose. Total dose rate alone is therefore a poor output to compare in such model inter-comparisons..

External dose rate generally contributed little to the overall total dose in the two scenarios considered. Therefore, differences in assumptions with regard to occupancy contribute little to the overall variation in estimated dose rates. However, assumptions with regard to diet, and concentration ratio (CR) values used to predict the activity concentration in dietary components, were responsible for variation observed between those participating models which use food chain approaches rather than simple biota-media CR values.

The scenarios also allowed comparison of the predictions of simple CR based approaches with more complex food-chain models under equilibrium conditions. Overall, the two approaches compared favourably. In the case of Perch Lake, two of the models which take into account water chemistry better predicted the transfer of <sup>90</sup>Sr to fish. Although it is likely that some of the CR based approaches were predicting soft tissue and not whole-body activity concentrations.

## **RECOMMENDATIONS**

The need for a system to protect the environment from ionising radiation is now generally recognised and environmental protection is referred to in the draft revision of IAEA Basic Safety Standards and new recommendations of the ICRP (ICRP 2007). However, many aspects including the discussion of protection goals, agreement of benchmark values and parameterisation of models applied in the work described here are still under development.

An aim of the BWG was to improve the models used by Members States. The collaborative exercises led to the sharing of parameters and re-parameterisation by some of the participating models. However, the model-model inter-comparisons and the scenario applications only compared a limited number of radionuclides. Additionally, whilst the scenarios considered sites for which extensive databases were available these may not (especially Chernobyl) be typical of situations needing to be assessed within regulatory frameworks. The work of the BWG will continue, in some form, within the follow-up programme to EMRAS. The following are the recommendations of the BWG members on the potential activities which should be considered within the future programme (in part, these are designed to aid the IAEA in the development of future guidance on the assessment of biota).

### **Transfer parameters**

The work of the BWG has clearly demonstrated that the largest contribution to variability between model predictions, and comparison with available data, is the parameterisation of their transfer components. There is a clear need to better share knowledge on the transfer of radionuclides to biota and provide authoritative collations of those data which are available. It is suggested that a document for biota which is equivalent to the IAEA handbook on transfer parameters for human food chains (IAEA, 1994) should be produced.

## **ICRP framework**

The outputs of the ICRP will clearly be something which the BWG should evaluate in any future scenario applications and model inter-comparisons.

## **Future scenarios**

Future scenarios should focus on situations which regulators/industry are having to consider. Such scenarios would enable the comparison of the available approaches within a regulatory context evaluating the various tiers of assessment.

## **Effects data**

The models used by the BWG predict dose rates to biota but there is also a need to be able to determine the potential consequences of predicted dose rates. A large amount of data on the effects of ionising radiation on biota has recently been collated into the FREDERICA data base (see [www.frederica-online.org](http://www.frederica-online.org)). This compilation can be used to aid in decision-making on the potential impact of the predicted exposure to ionising radiation. However, the effects data available in the FREDERICA database covers only a proportion of the available scientific literature. Furthermore, to be of most use to decision-makers there is a need to better evaluate the quality of much of these data to ensure that they are applicable. It is suggested that this could be best achieved through a subgroup of the BWG.

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