Radiation protection of the environment: providing knowledge and skills to the user community

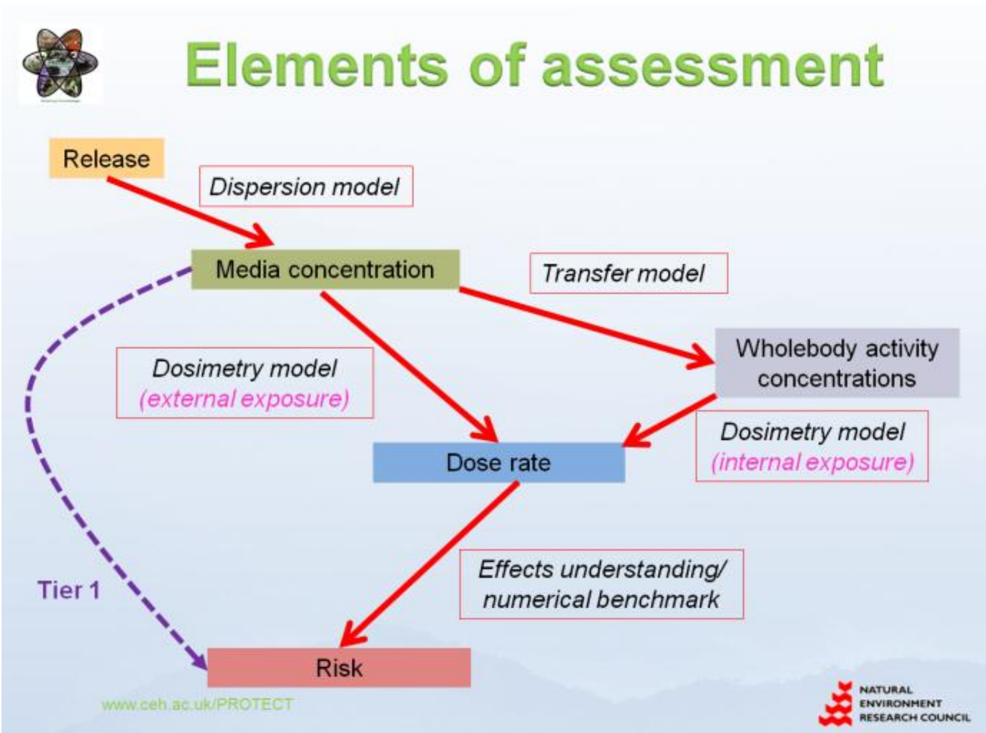
TRANSFER MODELS WITHIN RADIOLOGICAL ENVIRONMENTAL ASSESSMENT TOOLS

Objective of this briefing note

This document aims to provide a basic introductory overview to how transfer is modelled in environmental assessment models such as the ERICA Tool. More information will be provided in the course lectures and approaches used in other models will be introduced. Key references are provided for further reading.

Why do we need transfer models?

To determine the internal dose rate an organism receives we need to know the activity concentration in its tissues. Current radiological environmental assessment models consider wholebody dose rates (rather than organ specific dose rates) and consequently require wholebody activity concentrations to be input. Wholebody activity concentrations are used as the majority of the available radiation effects data are related to wholebody (external gamma exposure) dose rates.

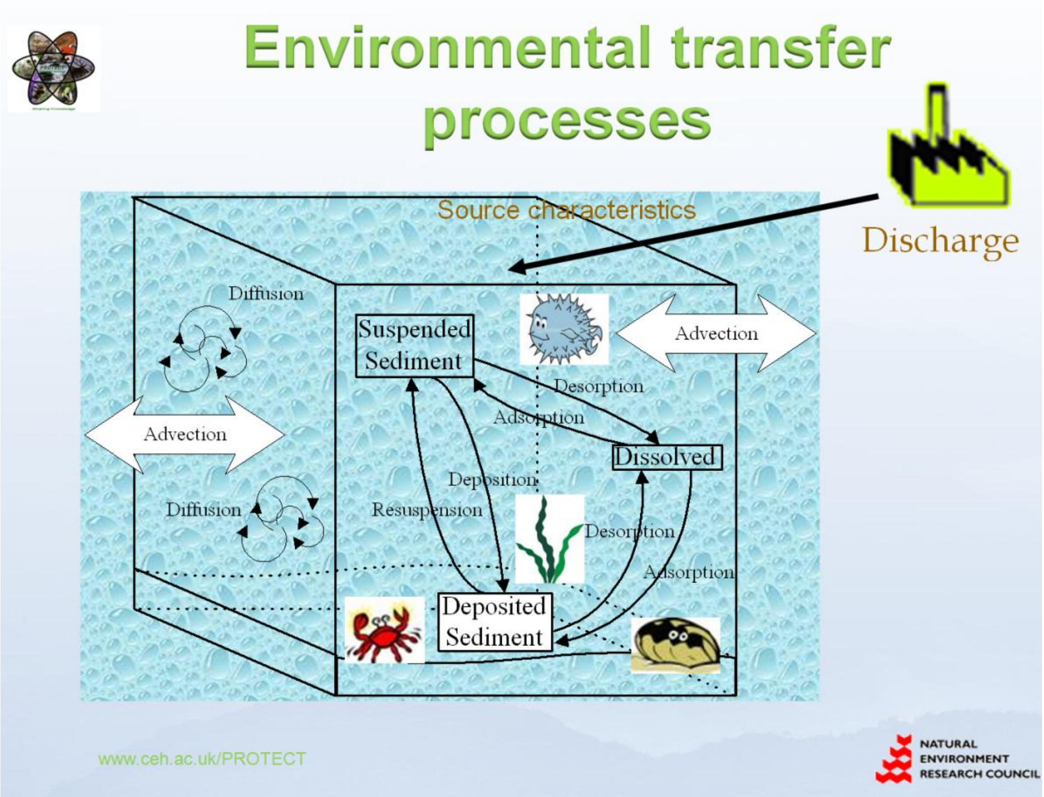


In some instances, monitoring data will be available as an input into the assessment tool which will then use these values to estimate wholebody dose rates. As most current monitoring programmes are focused on human foodstuffs, tissue specific data (e.g. for fish flesh) may require transforming into wholebody values (see http://wiki.ceh.ac.uk/x/MIIrBw for information on how to do this).

However, in many instance monitoring data will not be available for radionuclide-organism combinations of interest. This is likely to be the case for instance, if a Natura 2000 site is being assessed or in the case of a prospective assessment for a new facility. Therefore, we need a method of estimating wholebody activity concentrations based upon levels in environmental media (i.e. soil, water, sediment or air), i.e. we need a 'transfer model'.

Environmental transfer of radionuclides

The processes governing the transfer of radionuclides within the environment are complex and element specific.



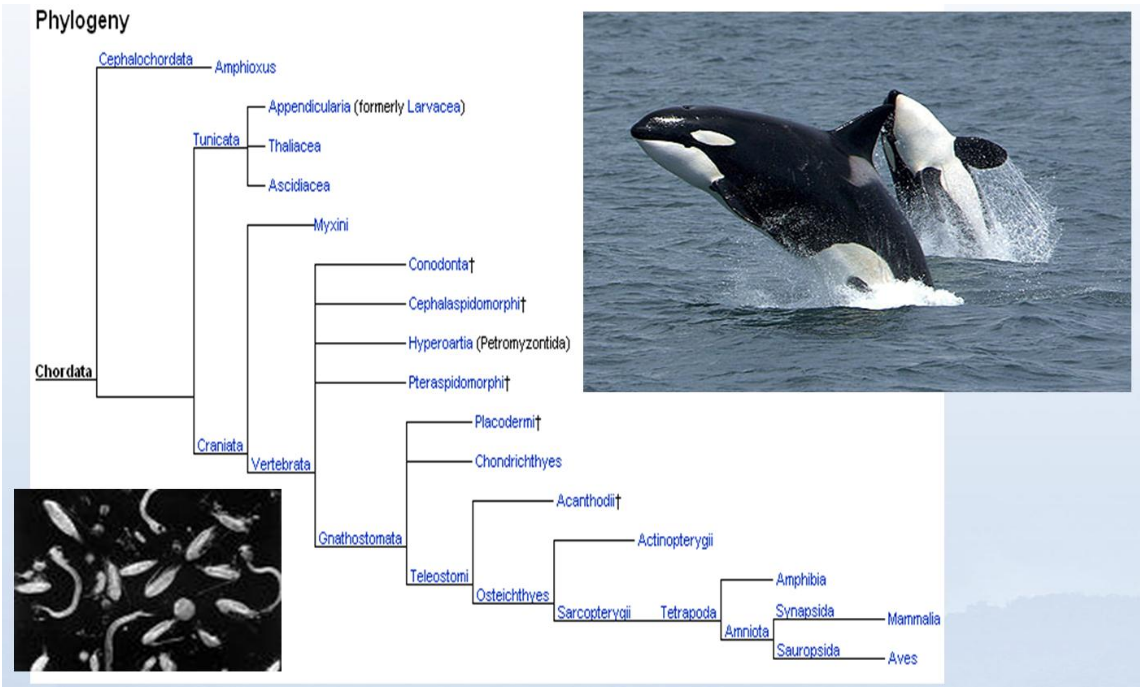
For instance, water chemistry and sediment characteristics, and soil mineralogy and chemistry are key factors determining the transfer of radionuclides in aquatic and terrestrial ecosystems respectively. The source term (i.e. nature of radionuclides released into the environment) may influence transfer in all ecosystem types. The transfer of radionuclides to animals from their diet can (depending upon radionuclide) be determined by factors such as the nutrient requirements of the animal and the form of radionuclide in their diet.

Useful descriptions of the factors influencing radionuclide transfer can be found in:

- International Atomic Energy Agency (IAEA) (2009) Quantification of radionuclide transfer in terrestrial and freshwater environments for radiological assessments. IAEA-TECDOC-1616. International Atomic Energy Agency, Vienna. (http://www-pub.iaea.org/MTCD/publications/PDF/te_1616_web.pdf)
- Smith JT & Beresford NA (eds) (2005) Chernobyl, Catastrophe and Consequences. Springer/Praxis Publishing, Chichester. (http://www.springer.com/earth+sciences+and+geography/book/978-3-540-23866-9)
- van der Stricht E, Kirchmann R (eds) (2001) Radioeology, Radioactivity & Ecosystems. International Union of Radioecology (IUR), Belgium.

Transfer in the ERICA Tool

There are a vast number of potential radionuclide-organism combinations which may need to be considered within an assessment. It is not feasible to develop mechanistic models for all of them.



Most of the available environmental radiological assessment approaches, including the ERICA Tool have simplified this issue by:

- considering a set of default organisms for which transfer parameters are derived;
- utilising organism-media concentration ratios (see following equations).

Reference Organisms were selected to encompass: different trophic levels (i.e. primary producers to carnivores); groups sensitive to ionising radiation (e.g. mammals); organisms likely to be comparatively highly exposed (e.g. sediment dwelling benthos); protected species. Data are then collated at the level of Reference Organism. Example Reference Organisms in the ERICA Tool are Tree, Mammal, Reptile, 'Grasses and herbs' in the terrestrial ecosystems, and Crustacean, Benthic Fish, Pelagic Fish, Phytoplankton in aquatic ecosystems.

Within the ERICA Tool the transfer model is highly simplified. All of the processes influencing transfer are basically 'lumped' into one parameter, the whole organism concentration ratio (CR_{wo}) which is the ratio of the wholebody activity concentrations relative to that in the appropriate environmental media. In terrestrial ecosystems, for most radionuclides, CR_{wo} is defined as:

$$CR_{\text{wo-soil}} = \frac{\text{Activity concentration in biota whole organism (Bq kg}^{-1}\text{ fresh weight)}}{\text{Activity concentration in soil (Bq kg}^{-1}\text{ dry weight)}}$$

The exceptions are some radionuclides released as chronic atmospheric emissions (e.g. ^{3}H, ^{14}C) are estimated as:

$$CR_{\text{wo-air}} = \frac{\text{Activity concentration in biota whole organism (Bq kg}^{-1}\text{ fresh weight)}}{\text{Activity concentration in air (Bq m}^{-3}\text{)}}$$

For aquatic ecosystems the majority of approaches calculate CR_{wo} as:

$$CR_{\text{wo-water}} = \frac{\text{Activity concentration in biota whole orgamism (Bq kg}^{-1}\text{ fresh weight)}}{\text{Activity concentration in water (Bq L}^{-1}\text{)}}$$

In aquatic systems the activity concentration in sediment is also required, to estimate external dose rates to benthic organisms. If this is not known then it can be estimated from the activity concentration in water by using the solid-liquid distribution coefficient (K_d) which describes the relative activity concentrations in soil solution and on soil solids:

$$K_d(L\ kg^{-1}) = \frac{activity\ concentration\ in\ solid\ phase\ (Bq\ kg^{-1})}{activity\ concentration\ in\ liquid\ phase\ (Bq\ L^{-1})}$$

If sediment activity concentrations are known but water concentrations are not, the K_d can be used to estimate activity concentrations in water.

The derivation of default transfer parameters used in the initial versions of the ERICA Tool (up to the 2014 release) can be found in:

- Beresford, N.A., Barnett, C.L., Howard, B.J., Scott, W.A., Brown, J.E., Copplestone D. 2008. Derivation of transfer parameters for use within the ERICA Tool and the default concentration ratios for terrestrial biota. *J. Environ. Radioact*., 99, 1393-1407. ABSTRACT
- Hosseini, A., Thorring, H., Brown, J.E., Saxen, R., Ilus, E. 2008.Transfer of radionuclides in aquatic ecosystems - Default concentration ratios for aquatic biota in the Erica Tool. *J. Environ. Radioact*., 99, 1408-1429. ABSTRACT

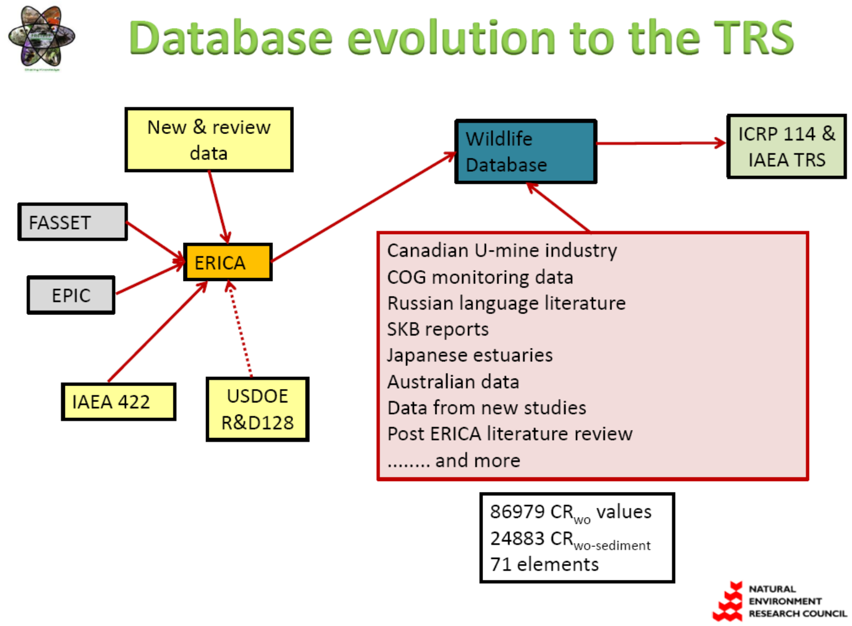
International initiatives and updates to the ERICA Tool transfer parameters

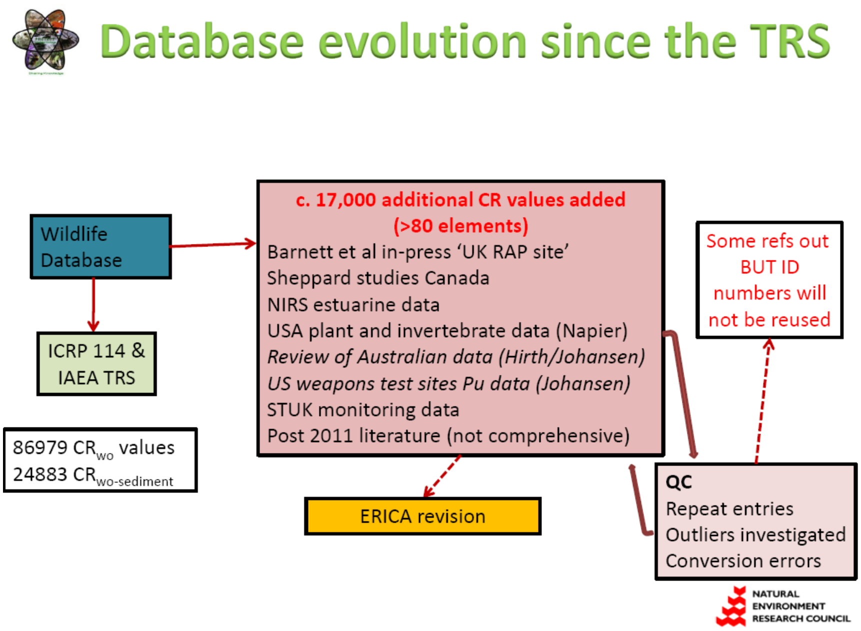
An on-line data base was created in 2009 to collate CR_{wo} values for wildlife. This was initially populated by the ERICA databases, after further quality control checks, given at that time they were the most comprehensive available. This initiative was conducted in collaboration with the IAEA and ICRP and these organisations have subsequently used the outputs to prepare reports presenting CR_{wo} values (see below). In the case of the IAEA data are presented for an expanded range of organisms and radionuclides. The ICRP report (Publication 114) presents data for the ICRPs Reference Animals and Plants which are defined at the family level. Subsequently the ICRP values are often based upon less data (i.e. being restricted to values for the appropriate taxonomic values) than those in the IAEA handbook or the 2014 update of the ERICA Tool.

The on-line data base contains tables summarising the available data at the time the ICRP and IAEA reports were produced (early 2011; see http://www.wildlifetransferdatabase.org/downloadsummary.asp). However, subsequently additional data have been added and the database further quality checked. This revised version (as of December 2013) has been used to create the CR_{wo} values as will be used within the revision of the ERICA Tool to be released in 2014 (see 'ERICA updates 2014' briefing note). Currently, the database is being used to provide updated CR_{wo} values for a screening assessment methodology being developed by the IAEA (to be published as a Safety Report Series).

Some issues have been identified with the approach to summarise data within the wildlife database – this largely relates to the calculation of geometric means and associated standard deviations (these are not used in the ERICA Tool) (see Wood et al. paper below).

The figures below demonstrate the evolution of the wildlife transfer database from European projects prior to the development of the ERICA Tool through to the 2014 ERICA Tool values ('TRS' – is the IAEA handbook which will be published under the Agency's Technical Report Series).





Relevant reading

ICRP report

P. Strand, N. Beresford, D. Copplestone, J. Godoy, L. Jianguo, R. Saxen, T. Yankovich, J. Brown. 2009. Environmental Protection: Transfer Parameters for Reference Animals and Plants. ICRP Publication 114. Ann. ICRP Vol 39 (6). Elsevier. http://www.icrp.org/publication.asp?id=ICRP%20Publication%20114

IAEA handbook (the IAEA handbook is currently, March 2014, in-press)

Howard, B.J. 2013. A new IAEA handbook quantifying the transfer of radionuclides to wildlife for assessment tools J. Environ. Radioact. 126, 284-287. http://dx.doi.org/10.1016/j.jenvrad.2013.11.002 (Special issue focussing on the IAEA handbook with some evaluation of values in it).

Howard, B.J., Beresford, N.A., Copplestone, D., Telleria, D., Proehl, G., Fesenko, S., Jeffree, R., Yankovich, T., Brown, J., Higley, K., Johansen, M., Mulye, H., Vandenhove, H., Gashchak, S., Wood, M.D., Takata, H., Andersson, P., Dale, P., Ryan, J., Bollhöfer, A., Doering, C., Barnett, C.L., and Wells, C. 2013. The IAEA Handbook on Radionuclide Transfer to Wildlife. J. Environ. Radioact. 121, 55–74 http://dx.doi.org/10.1016/j.jenvrad.2012.01.027

Yankovich, T., Beresford, N.A., Fesenko S., Fesenko, J., Phaneuf, M., Dagher, E., Outola, I., Andersson, P., Thiessen, K., Ryan, J., Wood, M.D., Bollhöfer, A., Barnett, C.L., Copplestone, D. 2013. Establishing a database of radionuclide transfer parameters for freshwater wildlife. J. Environ. Radioact. 126, 299-313. http://dx.doi.org/10.1016/j.jenvrad.2012.07.014

Wildlife transfer database

Copplestone, D., Beresford, N.A., Brown, J., Yankovich, T. 2013. An international database of radionuclide Concentration Ratios for wildlife: development and uses. J. Environ. Radioact. 126, 288-298. http://dx.doi.org/10.1016/j.jenvrad.2013.05.007

Wood, M.D., Beresford, N.A., Howard, B.J., Copplestone, D. 2013. Evaluating summarised radionuclide concentration ratio datasets for wildlife J. Environ. Radioact. 126, 314-325. http://dx.doi.org/10.1016/j.jenvrad.2013.07.022

Beresford N.A. 2010. The transfer of radionuclides to wildlife (Editorial). Radiation Environ Biophys., 49, 505-508. http://dx.doi.org/10.1007/s00411-010-0325-x (Special issue with a number of papers describing data contributed to the database)