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Updating Environmental Media Concentration Limits and Uncertainty factors in the ERICA Tool

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INTRODUCTION

Tiered approaches have become a standard means of structuring risk assessments for chemicals (European Food Safety Authority, 2013) and radioactivity (USDoE, 2002). For cases involving the assessment of impacts on wildlife from ionising radiation, the ERICA integrated approach and its supporting software, the ERICA Tool (Brown *et al.*, 2008), provides such a tiered structure. For this particular approach, there are two generic screening tiers and a third site-specific tier. The first Tier is very simple, based around Environmental Media Concentration Limits, EMCLs, and requires minimal input from the assessor. The second Tier, although still a screening tier, is used to calculate dose rates and requires more detailed input from the assessor allowing for scrutiny and editing of default parameters in the process. A key element of Tier 2 involves the application of Uncertainty Factors, UFs. Such factors reflect our knowledge concerning probability distribution functions and provide a way of incorporating conservatism into the assessment by considering high percentile values in underlying parameters.

Following its launch in 2007, there have been significant developments on technical subjects that may have ramifications for components of the ERICA integrated approach. Most notably, an extended international collation of concentration ratio data (Copplestone *et al.*, 2013) has precipitated the need to update parameter values in the Tools databases. In addition, more considered guidance has been developed with regards to filling knowledge gaps in the absence of transfer data (Brown et al., 2013). In this paper, we explore the implications of the developments in environmental impact assessment databases and methods in terms of derivation of EMCLs and UFs. The calculations used in deriving these parameters will be presented and information on the methodology adopted will be provided.

MATERIALS AND METHODS

EMCLs are defined as the activity concentration in the selected media: soil or air (H, C, S and P only) in terrestrial environments, water or sediment in aquatic environments that would result in a dose-rate to the most exposed organism equal to that of the selected screening dose-rate. The first stage in the EMCL derivation involves the calculation of intermediate EMCL values for all reference organisms for a selected radionuclide and media (Equation 1). The minimum intermediate EMCL value across all organisms is then selected to define the final EMCL value for a particular radionuclide. The limiting organism may be different for different radionuclides.

$$\mathrm{EMCL} = \frac{\mathrm{SDR}}{\mathrm{F}} \qquad (1)$$

Where: F = the maximum dose rate that an organism will receive for a unit activity concentration of a given radionuclide in an environmental medium (μGy h^{-1} per Bq l^{-1} (water) or per Bq kg^{-1} dry weight (soil) or per Bq m^{-3} (air) of medium); SDR = the screening dose rate (μGy h^{-1}) selected by the assessor at the assessment context stage (10 μGy h^{-1} is used as the default value in the ERICA approach)

In deriving F, the selection of the default location within the habitat is based on the configuration that will result in maximum exposure of the reference organism. For example, for the terrestrial burrowing mammal, the assumption is made that the organism spends 100% of its time underground, when in reality it will also spend much of its time at the soil surface. As an example of the equations used to estimate F, the case for a burrow mammal is provided in Equation 2, below.

$$F = \left[DCC_{\mathrm{int},bm} \cdot CR_{bm} + DCC_{ext,bm} \right] \qquad (2)$$

Where : $DCC_{int,bm}$ = internal dose conversion coefficient for soil invertebrate; CR_{bm} = concentration ratio for soil invertebrate; $DCC_{ext,bm}$ = external DCC for in-soil.

The full set of equations, covering all ecosystems and reference organisms, is provided in the Help function for the Tool. F values are calculated using all available information, which includes probability density functions of parameters for which these are available (namely CR values and sediment-water distribution coefficients for aquatic ecosystems). Calculations are performed probabilistically using a Monte Carlo approach resulting in a PDF for the F value from which any percentile of the F value can be selected. As the default, the 95th percentile F value has been selected for use in the calculations (i.e. this value is entered into Equation 1) to yield a 5th percentile EMCL.

In this study, new EMCL values have been generated using (i) the most recent CR values extracted from the Wildlife transfer database (Copplestone et al., 2013), (ii) application of an evolved CR data gap filling approach the originals of which are described in Beresford et al., (2008) and Hosseini et al. (2008); (iii) updated distribution coefficients, K_ds, from a reappraisal of values used earlier. Of particular note was the avoidance of using assumptions of exponential distributions as far as practicable (this assumption was commonly used in the initial Tool version). The original strict application of the principle of maximum entropy (Harr, 1987) was considered overly zealous in the sense that there was no fundamental reason to avoid using all available information on variance when the default values were provided by extrapolation approaches. Extension of the Central limit theorem also leads to the view that CRs and K_d should approach log-normal distributions (Sheppard, 2005).

At Tier 2, the estimated total (internal and external summed) weighted absorbed dose rates for each reference organism included in the assessment are compared directly with the dose rate screening value that was selected by the assessor for use in the assessment. This produces a risk quotient for each organism included in the assessment (Equation 3):

$$RQ_{org} = \frac{DR_{org}}{SDR} \tag{3}$$

Where: RQn = Risk quotient for reference organism “org”;DRn = estimated total dose rate (µGy h^{-1}) for reference organism “org”; SDR = the screening dose rate (µGy h^{-1}) selected by the assessor at the assessment context stage.

An uncertainty factor is used as a multiplier for this value to provide a conservative estimate of the risk quotient (based on the 95^{th} percentile from an exponential distribution). Further analyses of the appropriateness of UFs have been made, following comments by Thorne (2013), by applying different parameter distributions (log-normal) characterised by a range of geometric standard deviations.

RESULTS AND CONCLUSIONS

By way of example the newly generated EMCL values have been compared with the old values (Figure 1).

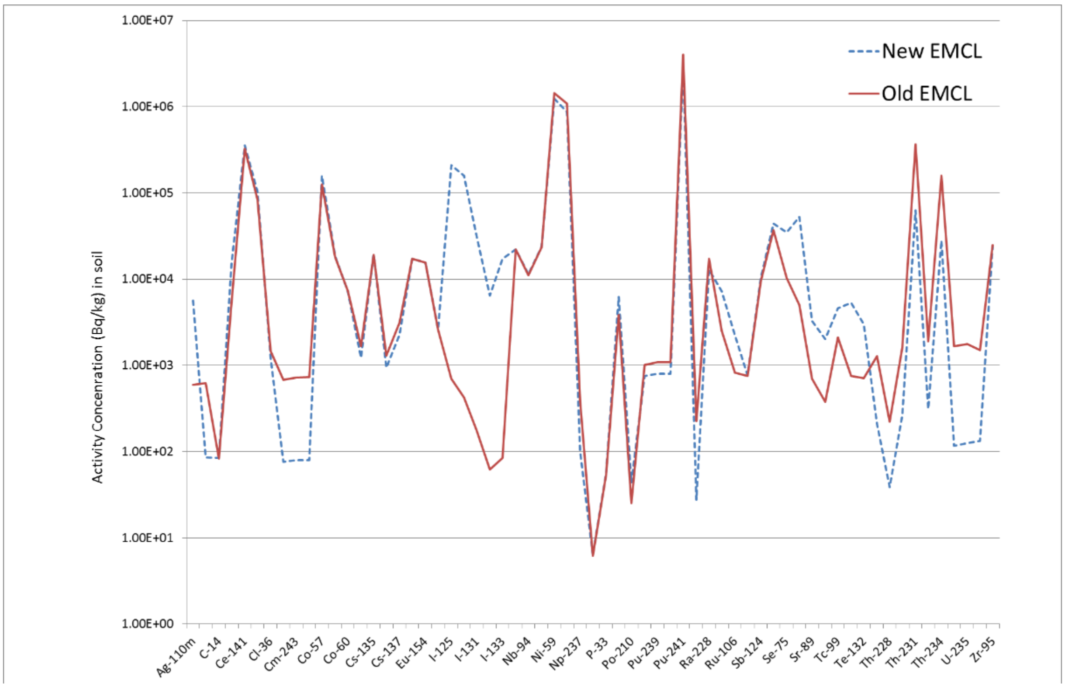

Figure 1. Old and new EMCL values for terrestrial ecosystem

Substantial differences are noted for isotopes of iodine where new EMCL values are two orders of magnitude higher than the old EMCLs. This undoubtedly reflects the removal of bird egg as a reference organism category owing to being inconsistent with how other organisms are considered and the lack of data and consequent requirement for pessimistic assumptions in the original ERICA Tool. The necessity of invoking conservative assumptions in the old EMCL derivation for these radioisotopes meant that EMCL values were correspondingly low. Other notable examples where differences are large can be found for isotopes of uranium where the new EMCL values are at least one order of magnitude lower than the old EMCLs. Although no changes have been made in the limiting organisms, namely lichen and bryophyte, a more robust characterisation of concentration ratios for this organism group explains the change. The new lichen and bryophyte CR value is based on 250 measurements whereas the number of data the old value was based upon was unspecified.

In (Avila et al., 2014) we argued that since in Tier 2 we only obtain expected values, then from the Maximum Entropy Method, we can only assume that RQs follow an exponential distribution when estimating UFs. We acknowledge that other approaches may be applied. In particular, we are aware of the arguments of Thorne (2013) that concern the fact that we often know more than just the expected value and that parameters like CRs are bounded by 0 at one end of the distribution and by a physical constraint at the upper end and hence do not fit comfortably with an exponential distribution. Nonetheless, the UFs generated for 95th percentiles using the exponential distribution assumption are similar to the values obtained for a lognormal distribution with Geometric standard deviation 3 (a value that might be considered a typical variance for a well-defined parameter) for the same percentile. The current approach is therefore reasonably robust although further consideration will be given to the requirement to adjust UFs in future releases of the Tool.

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