Assessment of Impact to Non-Human Biota from a Generic Waste Repository in the UK

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INTRODUCTION

The UK’s Nuclear Decommissioning Authority Radioactive Waste Management Directorate (NDA RWMD, formerly Nirex UK Ltd), has played a leading role in establishing knowledge on geological disposal of radioactive waste in the UK. In 2001, a study was commissioned of the potential impact of releases of radionuclides from a generic repository on plants and animals (Jones et al., 2003). More recently, the NDA commissioned Enviros Consulting to report on developments in policy and in approaches for assessing impacts of radioactivity on non-human biota, that have occurred since the previous study. A trial application of the ERICA assessment tool, to reassess the impact of releases from a generic deep repository using similar source data as used previously (Nirex, 2003), formed part of this work.

This paper summarises the results of the reassessment exercise; key differences between the two assessments are identified and explored. The applicability and capabilities of the ERICA tool to assessments of releases from a waste repository are discussed and priorities for future work are identified.

ASSESSMENT APPROACH

The first stage of this study was a review of advances in environmental radiation protection policy and methods for assessing radiation dose rates to non-human biota, since the previous assessment (Jones et al., 2003). As a consequence of this review, it was concluded that the assessment methodology, developed as part of the two EC projects FASSET (Larsson, 2004) and ERICA (Beresford et al., 2007), provided the most comprehensive approach currently available for undertaking such assessments. Following its release in June 2007, the ERICA assessment tool was employed for this purpose.

The ERICA assessment tool provides a tiered assessment approach. At the simplest level – Tier 1 – environmental activity concentrations may be compared directly with conservatively derived ‘Environmental Media Concentration Limits’ (EMCLs). A risk quotient is derived on the basis of the ratio of the maximum predicted concentration and the limiting value, modified by an uncertainty factor, as appropriate. Tier 2 provides a simple process for estimating dose rates, based on generically defined reference organisms and associated environmental transfer and dose conversion factors. A dose rate benchmark of 10 µGy h\(^{-1}\) is common to both tiers, although it is applied slightly differently in each case (Beresford et al., 2007). The ERICA tool provides a third tier, but this was not applied in this assessment.

The Nirex Generic post-closure Performance Assessment (GPA) (Nirex, 2003), includes the rate of release of 22 radionuclides to groundwater, from which a time series of activity concentrations in soil and pore water over a period of up to 1 million years post closure may be derived. However, in view

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2 Environmental Risks from Ionising Contaminants Programme (2004-2007)
of the preliminary nature of the present study, and the fact that the ERICA assessment tool cannot readily handle complex time series, peak concentrations of individual radionuclides in soil or water were used, for the purposes of this assessment, regardless of their time of occurrence. A simple conservative assumption of a dilution factor of 100 between activity concentrations in fresh waters and marine coastal systems was applied for the purposes of scoping.

The corresponding peak activity concentrations in notional terrestrial, freshwater and marine ecosystems were used in Tier 1 of the ERICA assessment tool. Data for the following radionuclides were not, however, included in this tier and so could not be considered in this phase of the assessment: $^{227}$Ac, $^{229}$Th, $^{231}$Pa and $^{233}$U.

At Tier 2 of the ERICA assessment tool, the objective of this study was primarily to consider the general applicability of the methodology to repository-based assessments. The choice of reference organisms was adapted to reflect the subterranean nature of the source. For example, an additional user-defined organism was defined within the terrestrial environment – a carnivorous mammal (fox) – on the basis of its potential for significant in-soil occupancy and its relatively high radio-sensitivity (as a mammal). The additional capability of Tier 2 of the tool to include nuclides additional to the default set was also tested, to include those noted above.

**PRELIMINARY RESULTS AND DISCUSSION**

The Tier 1 assessment demonstrated risk quotients of less than unity for all three ecosystems, using the default uncertainty factor of 3. This suggests that the dose rates to reference organisms would not be predicted to exceed a dose rate of around 3 µGy h$^{-1}$, under the conservative assumptions underlying the derivation of the ECMLs. Tier 1 of the assessment tool does not include data for the complete range of radionuclides considered to be of relevance. However, it should also be noted that the assumption that all radionuclides are at their peak activity concentration simultaneously is likely to be pessimistic; in reality, radionuclides will reach their peak at different times, by processes that are indicated by their migration rate through the geosphere and their radioactive half-life.

The Tier 2 assessment delivered results that were consistent with those of Tier 1. The maximum weighted absorbed dose rates associated with the peak media activity concentrations were 0.9 µGy h$^{-1}$ (freshwater ecosystem, phytoplankton); 0.02 µGy h$^{-1}$ (marine ecosystem, phytoplankton) and 0.03 µGy h$^{-1}$ (terrestrial ecosystem, carnivorous mammal). These values are significantly below the screening criterion proposed ERICA screening value of 10 µGy h$^{-1}$, and even further below the earlier dose rate values (United Nations, 1996 and IAEA, 1992) that have been commonly used as benchmarks.

The main contributory radionuclides differ amongst the different ecosystems and reference organisms. In the freshwater ecosystem, Np-237 was found to be the dominant radionuclide, for both insect larvae and phytoplankton. In general, however, natural series radionuclides dominate (Po-210, U-233, U-234 and Ra-226). The breakdown of dose rates predicted for the terrestrial system is illustrated in Figure 1.

As noted, lack of flexibility in the ERICA assessment tool makes it difficult to calculate the temporal development of impacts and to assess how much pessimism is introduced by use of peak concentrations. At the dose rates predicted in this assessment this may not be a major issue; however it is relatively straightforward to write code that addresses the ERICA databases directly so that complex datasets can be handled more easily (Watts *et al.*, 2008). The use of this approach for the freshwater ecosystem is illustrated in Figure 2; peak doses to phytoplankton are only slightly reduced at 0.88 µGy h$^{-1}$, but the time development is clearly seen, with peak doses occurring between $2\times10^5$ and $4\times10^5$ years post closure.
The differences between the contributing radionuclides in different organisms and ecosystems are largely a consequence of differences between the concentration ratios applied.

CONCLUSIONS

The peak activity concentrations predicted to arise from releases from a generic repository would not lead to a significant increase in environmental risk. Indeed, a substantial proportion of the calculated dose rates are due to natural series radionuclides at concentrations that are well below typical background levels.

In the previous study (Jones et al, 2003), the highest (weighted) absorbed dose rate in an aquatic system was predicted to be around 6.5 µGy h⁻¹, which is of the same order of magnitude as those predicted in the current study; the significance of the contribution of natural series radionuclides is also common to both studies. However, previously, the authors concluded that it was not possible to undertake a detailed assessment for the terrestrial system, due to the paucity of data on concentration ratios. While the derivation of default concentration factors, as part of the ERICA project, has now made assessment in this system possible, it should be noted that many of the concentration ratio values
have been based on extrapolation, for example from data for similar organisms or from nuclides that are considered to be biogeochemically similar (Beresford et al, 2007).

This exercise also revealed some drawbacks with use of the ERICA methodology and tool for this type of assessment, in addition to the lack of flexibility (discussed above) to deal with the type of complex time series of data that arise from a repository performance assessment.

While it was not an issue for this assessment, the exclusion of some important ecosystems from the ERICA tool may restrict its application in other circumstances, for example where an existing or future ecosystem may include wetlands or mires. Changes in climate, and the associated ecosystems, are also not easily accommodated. However, it is also questionable whether existing data, particularly on concentration ratios, are sufficiently robust to allow differentiation between different climates. In this study, concentration ratios for the user defined organism – the fox – were derived from an alternative data source (Brown et al, 2003). The consistency of these data within the default range and their relevance to a particular climate and ecosystem type would merit further consideration.

The robustness of individual concentration ratios is clearly dependent upon the derivation approach and the need for further sensitivity analysis was identified. A study to evaluate the pedigree of these data and the sensitivity of assessments of the long-term releases of long-lived radionuclides to these values would be valuable. Such a study has been proposed to take place as part of the BIOPROTA programme.

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REFERENCES


