# Assessment of the impact of radioactive disposals from the United Kingdom Low Level Waste Repository on the ecosystem

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## INTRODUCTION

The Low Level Waste Repository (LLWR) Site Licence Company (SLC) operates the Low Level Radioactive Waste Disposal Site near Drigg, West Cumbria, which is the UK's principal facility for the disposal of Low Level Radioactive Waste (LLW). Disposals are carried out under the terms of an Authorisation granted by the Environment Agency of England and Wales (EA) under the Radioactive Substances Act 1993.

A new Authorisation for continued operation of this site was granted in 2006. One of the key requirements under this Authorisation was for the operator to carry out a comprehensive study of the impact of radioactive discharges and disposals on ecosystems and wildlife species using the most up to date assessment framework, together with the results of relevant environmental monitoring, by May 2007.

This extended abstract will provide detail on the technical approach taken as part of this study.

## MATERIALS AND METHODS

In order to satisfy the requirements of the 2006 Authorisation, a comprehensive assessment of the radiological impacts to the ecosystem was undertaken comprising a tiered risk assessment commencing with a detailed desk based review, followed by the screening of relevant monitoring data from the site against generic assessment criteria concluding with a numerical modelling risk assessment.

Initially, the desk study included a review of European Community Natura 2000 sites as well as United Kingdom Sites of Special Scientific Interest (SSSI) in the West Cumbria area which may potentially be impacted by the LLWR.

Following this, existing LLWR groundwater and surface water radiological monitoring data was screened against draft levels set by the EA (EA, 2005) in order to provide a representation of impacts to ecosystems during the operational phase of the LLWR up to 2050 (at which time disposals to the LLWR were assumed to cease). These screening levels have been established in order to assess the impact of radioactivity on water bodies as required by the European Community (EC) Water Framework Directive (EC, 2000). If the activity concentration of a radionuclide in a water body is below its screening level then there is an insignificant effect on wildlife within the watercourse.

The activity levels of key radionuclides migrating into the biosphere for the post closure period of the LLWR (from 2050 to 50,000 years post closure) were then calculated using the GoldSim (Goldsim, 2006) software code. The results of these model assessments were input into a prototype version of the Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA, 2007) tool at both Tier 1 and, where required, Tier 2 level in order

to determine risk quotients to reference organisms in three ecosystems: freshwater, marine and terrestrial.

The ERICA Integrated Approach (Beresford *et al*. 2007a) is supported by the ERICA tool, which is a software programme that guides the user through the assessment process, keeps records and performs the necessary calculations to estimate dose rates to selected biota. The tool interacts with a number of databases and other functions that help the assessor to estimate environmental media activity concentrations, activity concentrations in biota, and dose rates to biota. The ERICA tool also interfaces with the FREDERICA radiation effects database, which is a compilation of the scientific literature on radiation effect experiments and field studies, organised around different wildlife groups and, for most data, broadly categorised according to four effect umbrella endpoints: morbidity, mortality, reproduction and mutation. The databases of the ERICA tool have been built around a number of reference organisms which are listed in Table 1. Each reference organism has its own specified geometry (and default transfer data) and is representative of either terrestrial, freshwater or marine ecosystems. The assessment element of the ERICA Integrated Approach is organised in three separate tiers, where satisfying certain criteria in Tiers 1 and 2 allows the user to exit the assessment process while being confident that the effects on biota are low or negligible, and that the situation requires no further action. Where the effects are not shown to be negligible, the assessment should continue to Tiers 2 and 3. Situations of concern should be assessed further in Tier 3, by making full use of all relevant information available through the Integrated Approach or elsewhere.

**Table 1:** Reference organisms for each ecosystem in the ERICA tool. The corresponding ICRP reference organisms and plants are given in brackets.

| Freshwater | Marine | Terrestrial |
|---|---|---|
| Amphibian (*frog*) | (Wading) bird (*duck*) | Amphibian (*frog*) |
| Benthic fish | Benthic fish (*flat fish*) | Bird (*duck*) |
| Bird (*duck*) | Bivalve mollusc | Bird egg (*duck egg*) |
| Bivalve mollusc | Crustacean (*crab*) | Detritivorous invertebrate |
| Crustacean | Macroalgae (*brown seaweed*) | Flying insects (*bee*) |
| Gastropod | Mammal | Gastropod |
| Insect larvae | Pelagic fish | Grasses & Herbs (*wild grass*) |
| Mammal | Phytoplankton | Lichen & bryophytes |
| Pelagic fish (*salmonid/trout*) | Polychaete worm | Mammal (*rat, deer*) |
| Phytoplankton | Reptile | Reptile |
| Vascular plant | Sea anemones/true corals | Shrub |
| Zooplankton | Vascular plant | Soil Invertebrate (*worm*) |
| | Zooplankton | Tree (*pine tree*) |

The following nuclides are included within the ERICA integrated approach: Ag, Am, C, Cd, Ce, Cl, Cm, Co, Cs, Eu, H, I, Mn, Nb, Ni, Np, P, Pb, Po, Pu, Ra, Ru, S, Sb, Se, Sr, Tc, Te, Th, U and Zr.

The ERICA Integrated approach has been applied to case studies in order to validate the ERICA assessment tool. Measured doses and observed radiation induced effects have been

compared with estimated doses and predicted effects from the ERICA tool (Beresford et al, 2007b).

## RESULTS AND CONCLUSIONS

Initially, all Natura 2000 sites and SSSIs were identified within a 5 Km radius of the LLWR Site. This area was felt to be sufficiently large to encompass those designated habitats that may be impacted by the LLWR.. Three SSSIs and one Natura 2000 site were identified within the set 5Km radius.

Following the identification of sites of ecological interest, results from monitoring samples taken from the LLWR site between January 1971 and October 2006 were screened against levels set by the EA for the activity concentration of radionuclides in water (EA, 2005) and also from US DOE wildlife assessment guidance (US DOE, 2002).

In general, there are proportionally fewer radionuclides exceeding the screening levels for total alpha and total beta in the samples taken during 2000-2006 compared with the earlier samples. In particular, only $^{137}$Cs, Pu-alpha, $^{90}$Sr, total alpha and total beta and $^{234}$U exceed the screening levels in the samples taken during 2000-2006. Of these radionuclides, only total alpha, total beta and $^{234}$U exceed both the EA and US DOE screening levels.

The results for total alpha measurements between 2000 and 2006 show that 63% of the samples exceed the EA screening levels and 2% exceed the US DOE screening levels. The results for total beta measurements between 2000 and 2006 show that 3% of the samples exceed the EA screening levels and 30% exceed the US DOE screening levels. $^{137}$Cs exceeds both the EA and US DOE screening levels before 2000 and exceeds the US screening levels after 2000. After 2000, $^{137}$Cs exceeds the US screening levels. Pu-alpha exceeds the EA screening level after 2000 and both the US and EA screening levels before 2000. $^{90}$Sr exceeds the US screening levels after 2000 and exceeds both the US and EA screening levels before 2000. Total beta screening levels are exceeded after 2000. $^{234}$U screening levels are exceeded post-2000 for the EA screening levels only.

This screening exercise allowed key radionuclides to be identified for modelling using the GoldSim code (GoldSim, 2006). This model was based largely on the models used in the 2002 Post-Closure Radiological Safety Assessment (PCRSA) (see BNFL 2002a,b.c). A single deterministic ‘best estimate’ model was prepared. The current assessment provides the most complete assessment of current and future impacts to wildlife and ecosystems from radioactive disposals at the LLWR to date. This model allowed key radionuclide doses to be calculated at the identified SSSI and Natura 2000 sites.

In order to calculate impacts to ecological receptors, a draft version of the ERICA tool (ERICA, 2007) was utilised. The full version of the tool was not available at the time of the study, nevertheless, the use of ERICA was sanctioned by the EA.

The ERICA assessment showed that modelled peak radionuclide concentrations in the first 4,000 years post-2050 were not sufficiently high as to cause potential impact to ecosystems or wildlife. Similarly, peak radionuclide concentrations up to 50,000 years post-2050 are not sufficiently high as to cause potential impact to the marine ecosystem or the nearby SSSI terrestrial ecosystem. Up to 50,000 years post-2050, doses to two other pertinent terrestrial ecosystems have been calculated to have a greater than 5% probability of exceeding the

selected screening dose rate for some organisms. These doses are dominated by impacts from $^{228}$Th. This was based on a number of conservative assumptions and in reality, this risk probability is likely to be reduced significantly.

It should be noted that doses to non-human biota have been calculated on the basis of the maximum concentrations in the environment, therefore, the total exposure to each organism has been calculated by treating the maximum dose from each radionuclide as being additive, irrespective of the time at which the peak concentrations occurred, which is clearly conservative. In addition, the calculations assume that the reference organisms occupy media with the highest level of radioactive contamination, 100% of the time.

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