A FIRST APPROACH TO ASSESSING FUTURE CLIMATE STATES IN THE UK OVER VERY LONG TIMESCALES: INPUT TO STUDIES OF THE INTEGRITY OF RADIOACTIVE WASTE REPOSITORIES

C. M. GOODESS, J. P. PALUTIKOF, and T. D. DAVIES
Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK

Abstract. Projected timescales for the transport of radionuclides from an undisturbed underground nuclear waste repository to the surface are in the range of tens of thousands to millions of years. Over these timescales major natural and potentially major anthropogenic changes in climate can be expected. As part of the UK disposal safety assessment programme, time-dependent models of the repository environment are being developed. The Climatic Research Unit has undertaken a study of relevant climatic change and climatic effects. This has required assessment of the probable range, succession and duration of major climate states likely to be experienced in the UK over very long timescales, up to $10^6$ yr. Two methodologies have been employed. The first uses the Milankovitch theory, which is considered to be the major cause of the Pleistocene glacial/interglacial cycles. The second involves empirical analysis of the long-term reconstructed climate record: no assumptions about the specific causes or mechanisms are made. A period of 'sub-tropical' climate is included in the sequence to represent a period of anthropogenically-induced greenhouse warming. The climate sequence established using these methods will form the basis for studying related processes, such as erosion and groundwater movement and transfer by vegetation, and their implications for radioactive waste disposal. This has involved the construction of instrumental climate analogues.

1. The UK Strategy for Radioactive Waste Disposal

In the UK, radioactive waste is classified as high level (HLW), intermediate level (ILW) or low level waste (LLW). This classification is broadly indicative of radioactivity levels. There are currently two existing UK disposal sites for LLW. All ILW produced in the UK is stored above ground at nuclear installations around the country. The UK strategy is that HLW should be stored at the surface for at least fifty years until levels of radioactivity and heat generation decay significantly.

The assessment of the suitability of different regions of the UK for a new combined LLW/ILW disposal site has begun with the definition and identification of suitable large-scale hydrogeological environments (Chapman et al., 1986). UK Nirex Ltd. Nuclear Industry Radioactive Waste Executive considered three major engineering options within the identified geologically-suitable areas which are outlined in a public consultation document (UK Nirex Ltd., 1987). These options are:
i) a deep repository on land (200–1000 m deep)
ii) a deep repository under the sea bed with tunnel access from the land
iii) a deep repository under the sea bed built and operated from offshore structures.

All three options are based on a strategy of containing the waste and using multiple barriers to delay releases. The most favoured option is now i). Waste will be immobilised, usually in a cementitious matrix, packaged in steel containers and encased in concrete in a deep underground repository. After the end of the operating period, about 50 years, the entire repository will be sealed.

2. Long Term Safety Assessment

Safe disposal of radioactive waste implies that site selection and repository design take into account the present-day and future characteristics of the physical, chemical and biological environment. At present, there is no cut-off to the period for which repository safety should be assessed although it would be inadvisable to carry out detailed assessments covering periods of millions of years into the future with the implication that predictions over such timescales can be exact. However, fully-detailed calculations can be made for shorter periods (10 000–100 000 yr, say), and less detailed assessments to $10^6$ yr, taking into account increasing model and data uncertainties. For the purpose of the present study, timescales up to $10^6$ yr were considered, although accepting increasing uncertainty with time. Over these timescales, natural and anthropogenically-induced changes in the environment can be expected to occur which may make the repository more, or less, secure and which may increase, or decrease, the radioactive doses and risks to individuals.

With respect to the engineered structure of the repository, safety studies may assume either a progressive degradation of the materials post-closure, or some cataclysmic event due to, for example, human intrusion or tectonic activity. The resulting release of radionuclides into the environment immediately surrounding the repository activates the pathways to the human environment, or biosphere.

Transport of radionuclides into the biosphere from deep repositories is most likely to occur by radionuclide migration in the groundwater (Bertozzi et al., 1985). Assuming that climatic and tectonic conditions remain similar to those of today, and that there is no human intrusion, movement along this pathway should be extremely slow. Deep burial under invariant conditions should prevent the appearance of radionuclides in the biosphere for many thousands of years which, in relation to their half-lives, reduces the risks to below the target currently set by the UK Department of the Environment.

To assume invariant conditions is, unfortunately, unreasonable. Perhaps the most obvious release mechanism involves direct exhumation of waste by glacial action. However, a range of environmental changes can occur which speed the movement of radionuclides through the groundwater or increase the risk of human contamination in some way. The natural pathway for radionuclide transport