Abstract. The borehole disposal concept (BDC) was originally developed by NECSA and more recently has been further developed by the IAEA as a safe and secure solution for the disposal of disused sealed radioactive sources (DSRS). The concept is based on disposal in narrow-diameter boreholes at a depth in excess of 30 m. This paper describes the series of iterative, peer-reviewed post-closure safety assessments that have been undertaken over the last 15-20 years to build confidence in the BDC as a safe long-term management option for DSRSs.

Key Words: borehole disposal concept, disused sealed radioactive sources, post-closure safety assessment.

1. Introduction

Many radioactive sources are sealed, with the radioactive materials firmly contained or bound within a suitable housing that is typically a few centimetres in diameter. In some cases, the activity of a source decays to a level below which it is no longer suitable for its original purpose. In others, the associated equipment may become obsolete, worn out or damaged and so can no longer be used. These radioactive sources are referred to as disused sealed radioactive sources (DSRS).

Disused sources may still be sufficiently radioactive to be hazardous to humans and the environment and therefore require careful management; experience shows that loss of control can lead to accidents and even fatalities. In some cases, it is possible to return DSRS to their manufacturer, however, this is not always possible.

For some isotopes, decay storage of DSRS for a few years will be enough for the associated radioactivity to decay to safe levels. For longer-lived isotopes, the source may remain potentially hazardous for hundreds or even thousands of years. For such sources, disposal is the only waste management option providing a safe and secure permanent solution.

Disposal in narrow-diameter boreholes can provide such a safe, permanent and economic solution, especially for those countries without other planned or actual deep repositories. The borehole disposal concept (BDC) was first proposed in 1995 during an IAEA course hosted by the South African Nuclear Energy Corporation (NECSA). Since then borehole disposal of DSRS has evolved from a conceptual idea to a well-defined concept offering an internationally accepted solution for a wide spectrum of DSRSs that can be implemented in a range different conditions. This evolution has been supported by a series of post-closure safety assessments that have investigated the concept’s key safety features, under varying disposal system conditions, to support the concept design and licensing processes and to facilitate its site-specific implementation. This series of assessments are described in this paper.
2. NECSA Post-closure Safety Assessments

A key publication during the first phase of the development of the BDC was [1] which:

- described the concept and its safety objectives;
- provided details of typical DSRS inventories of some African countries;
- defined two generic (illustrative) South African disposal sites to evaluate the concept;
- developed an initial generic design and scenarios to be used in future work.

A preliminary post-closure safety assessment and evaluation of the concept was then carried out and published in 2000 [2]. The assessment considered the disposal of Ra-226 needles at the two illustrative sites. The results showed that the concept met generally accepted safety criteria and it was recommended that further work should be undertaken to develop and refine the concept. As a consequence, a second, generic assessment was undertaken for NECSA for a representative inventory of ten radionuclides and explored a wide range of barriers (stainless steel, copper, lead, cement and bentonite), geospheres (arenaceous, argillaceous and crystalline), and biospheres (humid, seasonally humid and arid/semi-arid) [3]. Following completion this assessment was peer reviewed by an IAEA-convened team of international experts in 2005. The team concluded that the borehole disposal concept was demonstrated to be a safe, economic, practical and permanent means of disposing of DSRS and that it is likely to be applicable for a wide range of DSRS and for a wide range of hydrogeological and climatic environments [4].

3. IAEA Post-closure Safety Assessments

The NECSA assessments were used to inform the subsequent development of a generic post-closure safety assessment for the IAEA (the GSA) which considered an expanded set of 31 radionuclides disposed in a borehole comprising a series of stainless steel and cement barriers [5]. Following an international peer review of the GSA, the models used to evaluate the BDC’s safety were further developed to provide a more detailed representation of stainless steel corrosion and cement degradation under a range of different groundwater flow and chemical conditions.

Figure 1 summarises the two conceptual models used in the GSA where the disposal zone is located (i) in the unsaturated zone, and (ii) in the saturated zone. Both models assume that, after an initial period of containment (the duration of which is dependent upon site characteristics), the disposal packages are breached, resulting in the contamination of groundwater that is then pumped from an extraction borehole and used for drinking and irrigation. In the unsaturated case, rainwater percolates down from the surface, causing released radionuclides to migrate downwards, through the disposal zone and the rock below, into the underlying geosphere. In the saturated case, groundwater moves parallel to the ground surface, leaching released radionuclides from the disposal zone.

The GSA showed that the containment provided by the waste package would be sufficient for most radionuclides to decay to negligible levels. However, for some radionuclides, such as actinides, even the long waste package lifetimes are insufficient to allow them to decay to negligible levels. Nevertheless, the GSA indicated that quantities greater than TBq of the actinides could be accommodated, even if the disposal package was assumed to fail relatively early and hydrogeological conditions at the site were relatively unfavourable.
FIG. 1. GSA conceptual model for disposal in unsaturated (left) and saturated (right) conditions

The GSA’s scope has recently been extended to include the post-closure safety assessment of Category 1 and 2 sources [6]. Calculations have been undertaken to consider the thermal and radiolytic effects of the disposal of high activity Co-60 and Cs-137 sources. The results indicate activity levels that are at the maximum value acceptable from an operational perspective (i.e. around 3000 Ci) would be suitable for disposal using the BDC.


Subsequent to the initial completion of the GSA in 2008, it has provided a useful starting point and worked example for site-specific safety assessments that have been undertaken by a number of Member States from Africa and Asia to evaluate the BDC for the management of their DSRSs (see for example [7]). These assessments have shown that the BDC offers a safe disposal option for each Member State’s DSRSs and, as a result, applications for a licence to construct, operate and close a disposal borehole are currently being prepared in Ghana and Malaysia.

The IAEA has also supported the development of a software tool that can be used by Member States in their country-specific safety assessments (FIG. 2) [8]. It provides them with the capacity to undertake a scoping assessment of one or more potential sites for the BDC. The scoping tool allows rapid decision making by providing an early indication of the potential suitability of site(s) based on site-specific hydrological and geochemical characteristics and the country-specific inventory. It evaluates the containment provided by the waste packages in the post-closure period (through implementing the models developed in the GSA [5]) and has a conservative model of radionuclide transport through the borehole and surrounding geosphere with no retardation of radionuclides. It has been used in assessments in Ghana and Malaysia [7].
FIG. 2. Graphical user interface from the BDC scoping tool showing site geochemistry tab page

REFERENCES


