

ENGINEERED BARRIERS AND GEOLOGICAL DISPOSAL



A geological disposal system comprises a system of multiple barriers, both natural and man-made, to provide long-term isolation and containment of radioactive waste. Various geological formations are stable and potentially suitable for geological disposal. Engineered barriers are designed to work in an integrated fashion together with the host geological formation. Much research has been carried out to develop engineered barrier systems suitable for use in different host rocks and with different waste types. These studies continue both nationally and within the framework of multilateral international projects, in facilities such as underground research laboratories.



Engineered Barrier System

The typical main components of an engineered barrier system (EBS) are (i) the waste and, in particular, the physical form given to it; (ii) the disposal container; (iii) buffer and backfill materials that surround the container; and (iv) backfills, seals and plugs in tunnels, galleries, boreholes and shafts. The first three components contribute to containing the radionuclides present in the waste, especially during the time period when radioactivity levels are highest. The backfills, seals and plugs placed in tunnels, galleries, boreholes and shafts have the function of isolating the waste emplacement zones from other rock zones that are more prone to water flow.

Key factors to consider in the design of an EBS include: (i) the nature of the waste to be confined, including its

thermal load and fissile material contents; (ii) the mechanical properties of the host rock; (iii) the groundwater chemistry and the rate at which it may contact the disposal container; (iv) potential interactions between EBS materials and their surroundings; and (v) the evolution of the local conditions over time, e.g., in response to external factors such as glaciations. Thus, an effective EBS must be designed for the specific waste it must confine and for the environment and time periods over which isolation and containment must be maintained. Special consideration may also be given, in the design, to accommodating any retrievability requirements that may derive from national laws, regulations or stakeholder concerns.

Roles of the main EBS components

Waste form There are many types of radioactive waste forms. The function of a waste form is to immobilise the radionuclides in a matrix that will resist leaching, powdering, cracking and other modes of degradation. As an example, spent fuel when considered to be waste is in the form of durable ceramic pellets encased in corrosion resistant metals such as zirconium and aluminum alloys or stainless steel. Waste may sometimes be processed into physical forms such as special ceramics (e.g., Synroc), cementitious materials or glass.

Disposal container In order to better fulfill its function of containing the waste, the disposal container needs to be resistant to deformation and corrosion. A metal container designed to achieve this containment function typically uses either a corrosion-allowance approach or a corrosion-resistant approach. Carbon steel is an example of a corrosion-allowance material and is an option for a thick-walled con-

tainer that also resists deformation. Copper is an example of a corrosion-resistant material and, in fractured host rocks, it is one of the preferred container materials. The estimated lifetime of a disposal container with a thickness of ~5 cm copper is more than 100,000 years. A cast iron insert is often used to give mechanical strength to a copper container. Stainless steels, nickel-based alloys, and titanium-based alloys are other candidate materials for thin-walled concepts following the corrosion-resistance approach. Forged steel and ductile cast iron are also being considered.

Buffer and backfill materials The buffer or backfill immediately surrounding the disposal container typically have the functions of stabilizing the repository excavations, providing favourable thermo-hydro-mechanical-chemical conditions for preserving the disposal container, limiting water access to the disposal container and retarding both chemically →

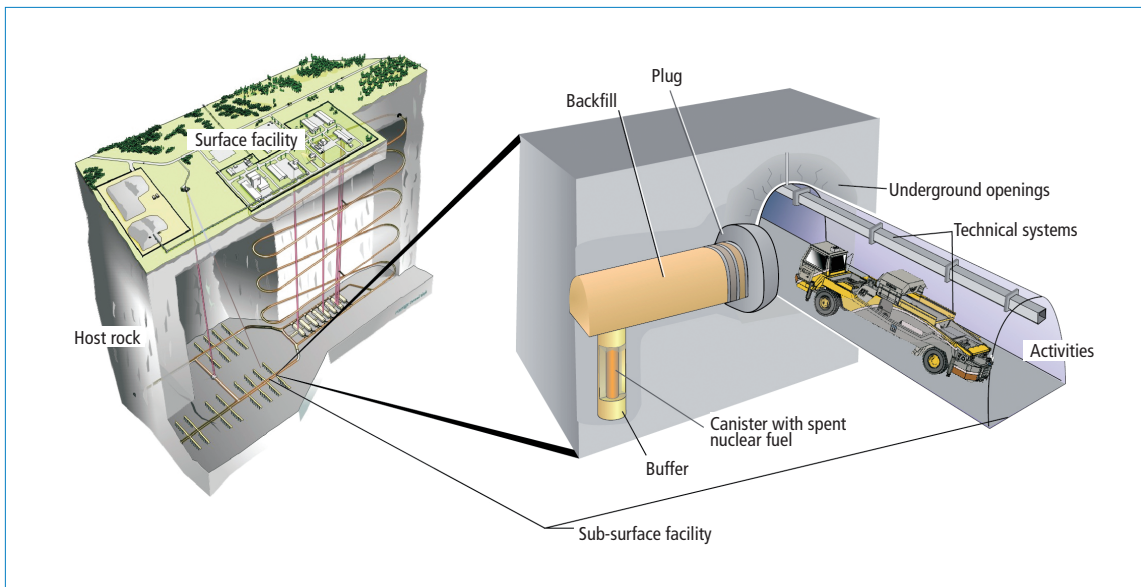


Figure 1: Example of an EBS within a geological disposal system (with the permission of SKB, Sweden)

→ and physically any radionuclide movement. Bentonite and cementitious materials are the common candidates for buffer materials in both crystalline rock and clay formations. Bentonites are often prepared in pre-compacted blocks. Highly alkaline cement buffer is also being considered in clay formations. In salt formations, crushed rock salt is an obvious choice since, as the rock has the ability to converge and seal itself under pressure after closure, the buffer or backfill material will attain characteristics similar to the host rock and become a confinement barrier.

Seals and Plugs Access tunnels and shafts of all repositories, regardless of rock types, must be sealed in order to

prevent access to the repository as well as to prevent water from easily reaching the waste. Seals and plugs are often made of concrete materials and bentonite clays for repositories in crystalline and sedimentary formations, whereas crushed salt seals are generally considered for a salt repository. Different types of plugs or seals are used at different stages of repository development. For instance, “temporary” tunnel plugs may be used during the operational period to avoid groundwater infiltration into the repository work areas or the swelling pressure of a wet backfill, whereas permanent seals may be placed at strategic locations in order to separate different deposition zones from rock zones that are more prone to water flow.

Where do we stand?

Research activities, carried out over the past few decades, have significantly advanced the development of engineered barrier systems designed for different geological settings, including their manufacturing and emplacement technologies. International collaborations have been formed to conduct experimental research to address fundamental physical and chemical processes of barrier materials and properties. Natural analogues of metals, backfill materials, and the natural geosphere have been studied to improve understanding of the relevant phenomena and their evolution over time. Research facilities have been built for the

manufacturing and testing of EBS components and demonstrations are performed in underground research laboratories under realistic conditions. Independent peer reviews are carried out to examine and assess the performance and behaviour of the various barrier components systematically. Although these studies and demonstrations have considerably enhanced confidence in the performance of the EBS, national radioactive waste management programmes are committed to continuing research activities in order to further verify and improve current knowledge and techniques.

GEOLOGICAL DISPOSAL IS THE PREFERRED METHOD FOR LONG TERM MANAGEMENT OF RADIOACTIVE WASTE. IN EACH REPOSITORY THE LONG-TERM ISOLATION AND CONTAINMENT OF THE WASTE IS ACHIEVED BY THE HOST GEOLOGICAL FORMATION AND THE SYSTEM OF ENGINEERED BARRIERS. ANY ENGINEERED BARRIER SYSTEM (EBS) IS MADE OF SEVERAL COMPONENTS, EACH TAKING DIFFERENT SAFETY ROLES THAT ARE RELIED UPON AT DIFFERENT TIMES IN THE LIFETIME OF THE REPOSITORY. RESEARCH, DEMONSTRATION AND DEVELOPMENT OF EBS MATERIALS, AS WELL AS OF THEIR MANUFACTURING AND EMBLEMMENT TECHNOLOGIES ARE IMPORTANT ENDEAVOURS IN NATIONAL WASTE MANAGEMENT PROGRAMMES AND THE SUBJECT OF INTERNATIONAL COOPERATION. THESE STUDIES AND DEMONSTRATIONS HAVE CONSIDERABLY ENHANCED CONFIDENCE IN THE PRODUCTION OF THE EBS COMPONENTS AND IN THEIR PERFORMANCE UNDER REPOSITORY CONDITIONS.