GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

Disposing of the radioactive waste products from nuclear sites is one of the most difficult challenges for society in the 21st century. Internationally, it is now accepted that burying radioactive waste deep underground in a Geological Disposal Facility (GDF) is the safest way to achieve this. There are guidelines drawn up by the IAEA, and several countries already have advanced plans. In the UK, a range of alternatives were evaluated by the independent expert Committee on Radioactive Waste Management (CoRWM) whose 2006 report favoured geological disposal.

In a GDF, the waste is contained within engineered barriers but the surrounding rocks provide an essential further barrier to prevent radioactive materials from the surface. The rocks that host a GDF must provide a stable environment for construction of tunnels and vaults, and also not contain potential future mineral resources. The rock must restrict or prevent the flow of groundwater through the GDF once it has been sealed, minimizing the risk that radionuclides could be taken up into solution and transported to the surface. Understanding groundwater at a site is vital.

Fluids such as water, brine, oil and gas occur in rocks in two distinct ways: they may occupy pores spread throughout the rock, or they may occur in cracks. Many sedimentary rocks are porous. In some, such as sandstone (Figure 2), pores are commonly well-connected and fluid moves through them easily making the rock permeable. In others, such as clays, pores are extremely small and fluids cannot move between them. These rocks are impermeable even if they have high porosity. Rocks are permeable, water only flows if there is a driving force. In the UK it is unusual for fresh, potable groundwater to extend more than a few hundred metres below the surface. Deeper rocks generally contain dense saline water which does not mix with overlying fresh water and is probably very old (>10000 years) (Figure 4).

Irrespective of rock types, the presence of old, dense, stagnant groundwater at a site is vital. Fluids such as water, brine, oil and gas occur in rocks in two distinct ways: they may occupy pores spread throughout the rock, or they may occur in cracks. Many sedimentary rocks are porous. In some, such as sandstone (Figure 2), pores are commonly well-connected and fluid moves through them easily making the rock permeable. In others, such as clays, pores are extremely small and fluids cannot move between them. These rocks are impermeable even if they have high porosity.
Groundwater at depth is a sign that radionuclides from a GDF will not be readily transported back to the surface, even over geological timescales, whereas if the groundwater is potable and young, there will be concerns that this could happen.

Internationally, three types of geological setting have been proposed as hosts for a GDF. Much early effort went into designing repositories in salt deposits. This is because salt provides an effective radiation shield, is impermeable to water and slowly flows underground, so that the cavities created to build the repository will naturally infill. The facility in New Mexico is hosted in salt. Other countries, including France and Switzerland, are planning to build their GDFs in clay or mudrock. Clays are impermeable and so provide a very effective natural barrier to the migration of radionuclides. Furthermore clays absorb many types of radionuclide from solution and so further retard their spread. Like salt, clays are weak and will flow, thus self-sealing cavities. Sweden and Finland are constructing repositories in strong granitic rocks with low permeability. The rock provides strength and impermeability which facilitates construction and operation, while clay packing can be used to further isolate canisters of HLW or SF. The possibility of groundwater flow along fractures requires careful site selection but deep groundwaters in strong rocks are often distinct from shallow ones (Figure 4). Another option for a GDF constructed in strong rocks is a site where the GDF host rock is overlain by impermeable rocks such as clays.

Over the next few years, RWM will be screening the geology of England, Wales and Northern Ireland and, after public engagement and independent oversight, will publish the available information about geological properties that influence the suitability of rocks to host a GDF. What these precise properties are will be a matter for much discussion over the coming months, and only then will regional geology be evaluated. With geological guidance in place, communities throughout the UK will be invited to consider hosting a GDF, provided their geological setting offers good prospects.

For simplicity, unsaturated rocks close to the surface are not shown. On the left, fractures in crystalline basement rock retain stagnant saline waters at depth (dark blue) but have been flushed by fresh water (light blue) at shallower levels. They are overlain by a range of sedimentary rock types. While the coarser sediments contain freshwater in their pores, the clays retain old saline pore waters except near their margins. A similar range of rocks is shown on the right, but in a different sequence and no basement is present. Again, deep rocks retain old pore waters.