FORGEing a safe future for radioactive waste

Fifty years of nuclear power generation in the UK have produced a significant amount of waste, and storing it is not straightforward. Radiation isn't the only problem – the waste produces potentially dangerous gases too. Emma Ward, Rob Cuss, Andy Kingdon and Richard Shaw are part of an international project working out what to do about it.

The large-scale gas injection test at the -420m level.

Flow apparatus which can simulate pressure conditions found in deep geological environments.

Working out what to do with nuclear waste is a complex problem. The use of nuclear power has always been an emotive subject and disposing of what's left over is no less so.

Many countries, including the UK, have decided that burial deep underground is the best way to make sure waste is disposed of safely, without causing a long-term hazard to humans and the environment. But burial isn't the end of the story. Once in its underground repository, the waste won't sit around quietly emitting radiation; it continues to be affected by a number of physical and chemical processes that generate problems of their own. Metal corrosion and radiolysis (the breakdown of water by radiation) produce hydrogen, for example, and some wastes contain organic material that generates methane and carbon dioxide as it decomposes. The best location for a repository is one where gases can't flow too freely and dissolve slowly, so that gas pressure doesn't build up and fracture the host rock. So understanding where and how these gases form and how they move through the repository and surrounding rocks is crucial, and this is the focus of the FORGE (fate of repository gases) project.

FORGE helps the national organisations responsible for safe radioactive waste disposal to understand how gas will flow around and out of the proposed repository once it is closed, so that everyone can be sure the process is safe.

The four-year project, funded by the European Commission under the Framework 7 Euratom Program, has 24 partners from 12 European countries, including national radioactive waste management organisations, regulators, research institutes and universities at the forefront of research in this area.

But how do you find out what's going to happen to radioactive waste buried hundreds of metres underground? We're approaching this question through a combination of laboratory experiments, large-scale field tests at a number of underground research laboratories across Europe, and detailed numerical modelling.

Underground disposal is based on the 'multiple barrier concept', which means the waste is sealed inside a series of man-made and natural barriers. Across Europe a number of options are being considered which use different types of rock to build the repository, including plastic clays, mudstones and crystalline formations. In most of these, either a type of clay called bentonite or cement-based materials are used to backfill the spaces between the waste containers and the walls of the excavation.

The waste will need to be buried for between 100,000 and one million years: it's a long time, and it's important to get it right. But an experimental approach alone can't give us all the answers. Most experiments can only be successfully operated for a few years at a time, so FORGE uses mathematical modelling of potential future conditions to get a more complete picture.

Modelling is always a difficult process. It uses mathematical algorithms to replicate natural processes, but to do this we have to simplify complex natural systems down to just a few variables to represent the properties of features such as the host rocks, groundwater flow and gas generation. If we choose the wrong ones, our model won't replicate the natural environment accurately enough, and it won't be much use.

To get the best possible results, FORGE's approach is to fully integrate laboratory and field experiment data with mathematical modelling. Our modellers and experimentalists exchange data and collaborate closely, and as a result our models represent the geological information better than ever before.

Ground breaking

One of our full-scale *in situ* experiments is LASGIT (large-scale gas injection test). It studies the movement of gas through bentonite clay in a mock deposition hole, 420m down in the Äspö Hard Rock Laboratory in Sweden.

LASGIT has two stages, each of which lasts about a year. In the hydration phase the bentonite is saturated with water and we monitor the suction (swelling) and pressure. In the second phase gas is injected into the clay, and we watch how it flows through the rock. So we get data on the movement of both water and gas through the bentonite buffer and the relationship between gas flow and pressure within the clay.

Another crucial part of the field test involves critical stress theory. Essentially this tells us that fractures or faults at certain orientations to stresses in the surrounding rock will act as barriers to gas flow, while those at other orientations will act as conduits – something we've seen in natural gas reservoirs. So this part of the experimental programme looks at the relationship between fractures and stresses in the repository. We're interested in two distinct areas; close to the repository, where the construction process will have created a complex local stress field with lots of fractures of different orientations; and farther away where the natural fractures in the rock are undisturbed by construction.

Thanks to some new British Geological Survey equipment we've been able to test critical stress theory in repository conditions for the first time. By injecting gas (or fluid) into the plane of the fracture at an angle to the applied stresses we can see how the gas flows and so work out which stresses will help the gas move and which will seal the fault and stop the gas flowing.

This work is important because building a repository changes the stresses in the surrounding rocks. Construction methods that cause the least fluid and gas flow are going to minimise the release of repository gas, so this knowledge helps us determine the best design and orientation for a repository.

FORGE is playing a key role in enhancing and developing European expertise in gas migration, helping to ensure that the partners are global leaders in this fast-developing and important area of science. ■

MORE INFORMATION

The British Geological Survey (BGS) is one of two UK partners in FORGE. Emma Ward is based at BGS Keyworth.
E-mail: forge@bgs.ac.uk
www.FORGEProject.org