Editor's Message
Nuclear waste disposal in Switzerland: science, politics and uncertainty

Simon Loew, Associate Editor

In Switzerland, radioactive waste arises from electricity produced by five nuclear power plants and from the use of radioactive materials in the fields of medicine, industry and research. The waste is grouped into three categories: High-level waste (HLW) including spent fuel, Long-lived intermediate-level waste (LILW), and Low- and intermediate-level waste (L/ILW). It is foreseen that a maximum of 100,000 m^3 of conditioned and packaged radioactive waste will arise in Switzerland over a period of 40 years. Based on current knowledge, geological disposal is the only method for isolating radioactive waste, which fulfils the requirement for long-term safety. Two different types of geologic repositories are foreseen in Switzerland: a deep repository at a depth between 400 and 1,000 m in the flat alpine foreland for HLW/LILW (accessed through vertical shafts or a ramp), and an intermediate-depth repository in the alpine belt for L/ILW (accessed through a horizontal tunnel). Recently it has been proposed that these repositories shall be built as monitored geological disposal facilities, where the backfilling of access tunnels is delayed for several decades. The behaviour of the safety barriers shall be monitored through long-term experiments in a so-called pilot facility, which is situated just beside the sealed main disposal area.

The federal government and its experts have established legal and political procedures and protection objectives for these repositories. The Swiss Federal Nuclear Safety Inspectorate HSK has published the official requirements for geological disposal in the year 1993 (R 21 guideline). The provisions in this guideline apply to all methods of geological disposal in Switzerland and to all categories of radioactive waste intended for disposal. They relate exclusively to long-term safety following closure of a repository. The overall objective of geological disposal is to protect human health and the environment permanently against radiation from the wastes. The two most important Swiss protection objectives are as follows:

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Protection objective 1
The release of radionuclides from a sealed repository, subject to the processes and events that may reasonably be expected to occur during its lifetime, shall at no time give rise to individual doses that exceed 0.1 mSv/year.

Protection objective 2
The individual radiological risk of a fatality arising from a sealed repository, subsequent to processes and events not considered under protection objective 1, shall at no time exceed one in a million/year.

These objectives recognize humans as being radiation-sensitive organisms and thus, released radiation into the population must not exceed a fraction of the dose normally received from natural background radiation. If the human population is rigorously protected from radiation exposure, it is assumed that other living organisms will likewise be protected. These objectives are integral to the protection of our natural environment and are not limited to any specific time limits. In the licensing procedure, the applicant (the Swiss nuclear waste producers) must demonstrate by means of a safety analysis that its proposal fulfils these requirements. Because of the integral nature of these objectives, the corresponding safety analyses must be based on model calculations incorporating the full complexity inherent in these systems.

Two strongly different aspects of these protection objectives will be briefly discussed. The first relates to the mismatch between the know-how of scientists involved in assessing these objectives for a given nuclear waste site and the knowledge of the local population living near the site. The second aspect deals with the challenges these objectives pose to the specialists and safety authorities involved.

In Switzerland (as elsewhere), the site investigation and safety assessment technologies developed during the last 20 years have reached a very high scientific and technical level (greatly exceeding that used to evaluate municipal and chemical waste disposal sites). Even for most professional engineers and geologist, who are not

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necessarily trained in the nuclear waste disposal field, it is very difficult to evaluate the results from the corresponding safety analyses. This has lead to the call for more specific, and if possible, directly measurable site evaluation criteria.

During the many years of democratic political arguments about potential sites for L/ILW and HLW in Switzerland, such site evaluation criteria have been agreed upon formally (although they have not been written into nuclear waste disposal regulations). They depend on the stage/progress of investigation at a given site and the type of waste/repository called for. In the Swiss HLM/LILW repository program, a potential host rock (Opalinus Clay) and disposal region (Zürcher Weinland) has recently been identified after 20 years of site evaluation and field investigation work. Key criteria evaluated during the site selection process include the isolation capacity of the host rock, seismic and geodynamic stability, fault pattern, depth and volume of host rock, groundwater flow properties, and explorability. In the L/ILW program, several investigations at various locations led to the proposition in 1993 of a potential host rock (Valanginian Marl) at a pre-alpine site (Wellenberg). This site was subsequently studied in great detail during the following years until the construction of an exploration drift was required to allow further geological/hydrogeological investigation. Site exclusion criteria were agreed upon prior to the construction of this drift, including the spatial distribution of low conductivity host rock, the rate of groundwater inflow into the drift, and the groundwater chemistry.

Even with such measurable and clearly defined criteria, a few scientific reviewers did not agree to the conclusions drawn by the specialists of the applicant and regulator involved in the site characterisation and selection process. Political, social and/or personal motivations significantly influenced scientific statements made by earth scientists, giving politicians the required arguments used in public debates. This was only one of many reasons that in 2002, the application for a concession for an exploratory drift of the Wellenberg site was rejected by the people of the State of Nidwalden (57% against 43%), causing a major stop in the L/ILW program. Although the Federal Council had already granted the licence for this drift and the Cantonal Government had already granted the necessary concessions, the ensuing political developments require that today we must re-evaluate the entire L/ILW disposal concept, discussing and defining new legal constraints on a national level. A new Nuclear Energy Law that clarifies the roles of various stakeholders has recently passed the Swiss Parliament and was published for public discussion.

Turning to the challenges that the Swiss protection objectives pose to nuclear waste disposal professionals, the assessment of the specific site criteria discussed above is a relatively easy task compared to the evaluation of the two protection objectives described above. For example, it is already known that for a HLW/LILW repository in a highly overconsolidated claystone at 600–800 m depth (Opalinus Clay), complex coupled thermo-hydro-mechanical (and geochemical) processes exist influencing the behaviour of the host rock. Fractures in the excavation-disturbed zone (EDZ) develop in response to the excavation of shafts, drifts and caverns. These fractures conduct fluids and gases and change their properties in response to swelling bentonite backfill, the heat pulse generated from waste, geochemical reactions, and fluid and gas pressures derived from the geosphere and/or waste. Aspects of these processes are the subjects of current studies in underground test facilities such as Mont Terri and in other ordinary laboratories involving sophisticated experiments, but are limited with respect to the selected coupled process components and are rarely at the scale of the disposal project.

As an engineering geologist who is also involved in several big tunnelling projects, this writer had to learn in the past that nature (the rock mass) sometimes looks very different from what is expected and reacts in new and unexpected modes. Sometimes, such surprises were encountered in areas where it was thought that the geology would be simple and well known. In tunnelling, the time scales between exploration, prediction, design and construction are in the order of 10 years; the operational phase lasts approximately 100 years. For nuclear waste repositories the time scales involved are obviously completely different and in the case of the Swiss protection objectives, there are no time limits. Robust (simple) scenario analyses and monitored geological disposal facilities help to reduce some of the corresponding uncertainties but they will not allow detailed prediction of what will happen in a couple hundred thousand years. Therefore the limits of current knowledge and the uncertainty of predictions both in space, time and conceptual understanding should be carefully discussed.

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