UNDERGROUND RESEARCH LABORATORIES (URLs) AND GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

Final disposal in engineered repositories built deep underground in stable geological formations with low groundwater flow is the ultimate end-point for managing long-lived highly radioactive waste. Underground research laboratories (URLs) provide a realistic environment for characterizing the selected geological settings, testing the relevant engineering solutions and materials, and demonstrating the feasibility of disposal to a wide range of stakeholders.

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A geological repository is a unique nuclear facility

Geological disposal refers to the emplacement of solid radioactive waste in a facility constructed at several hundred meters depth in a geological formation that is carefully selected to be stable and low groundwater flow. Great care is exercised in characterizing the site, and in excavating, constructing and operating the repository so that perturbations - thermal, chemical, hydrogeological and mechanical - to the initial state of the host environment are minimized. Great care is also taken in sealing all excavated conduits to the surface environment as well as from one repository chamber to another so that water ingress and movement are minimized. Finally, all engineered barriers are conceived to be compatible with the host geology providing multiple and redundant safety functions from the man-made and the natural barrier. Overall, the repository is conceived and licensed as a nuclear facility and must adhere to the highest quality requirements and safety of operation. Final reliance on passive safety, much beyond the actual operation of the facility, is an important distinguishing feature of a geological repository. URLs are needed to help develop such unique and high technological facilities.

What is an underground research laboratory?

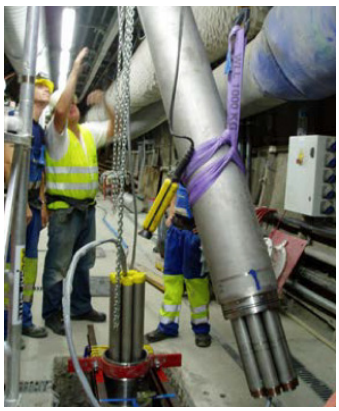
A URL is an underground facility for acquiring expertise to develop a nuclear waste repository. URLs are located in geological environments that are suitable for repository implementation or that offer realistic representations of those environments. They are constructed at depth of a few hundred meters or may be closer to the surface. URLs allow for building technical teams that integrate a wide range of scientific disciplines and for gaining practical experience in obtaining geological data, testing the relevant engineering solutions and materials in a manner that is transferable to actual repository operation and to the safety analyses. They also provide for a concrete illustration of what a geological repository may look like and contribute to confidence building also by the general public.

Types of URLs

Two broad categories of URLs may be distinguished: **generic URLs** and **site specific URLs**.

§ **Generic URLs** offer a geological environment for experimentation but not necessarily one that closely mimics the final repository. They help create generic expertise for working and acquiring technical data in an underground environment. Early generic URLs were sometimes created in pre-existing mines: the Stripa mine in granitic rock (1976-1992), in Sweden; the Tono mine in sedimentary rock (1986-2004), in Japan. In Switzerland and France, generic URLs have been built near tunnels: at Grimsel in granitic rock (1984), at Mont Terri in hard clay (1995), at Tournemire in hard clay (1992). Others have been purpose-built at depth: Whiteshell in granitic rock (1982-2010), in Canada; HADES in a soft clay formation (1980), in Belgium, and, more recently, Mizunami in granitic rock (2003) and Horonobe in sedimentary rock (2005), in Japan, and KURT in granitic rock (2006), in Korea.

§ **Site-specific URLs** are built in the same formation as the planned repository or in one that that closely mimicks the characteristics of the one of the final repository. They allow the specialization of the expertise in testing procedures and in obtaining data under conditions that are relevant to the performance of the final repository. Examples include: in the USA, WIPP in bedded salt (1982) and Yucca Mountain in tuff (1996-2009); in Germany, Gorleben in a salt dome (1990); in Sweden, Äspö in granitic rock (1995); in Finland, Onkalo in granitic rock (2004); and in France, the Meuse/Haute-Marne URL in hard clay (2004). In most cases, site



Experiments being conducted at the Meuse/Haute-Marne URL in France

specific URLs are seen as the precursors or the initial stage of developing a repository in the same geological formation. Äspö is the notable exception.

In the future, new types of site-specific URLs may be developed. That is, instrumented facilities at repository level reproducing parts of the repository for performance confirmation purposes.

URLs are expensive but valuable facilities

Construction and operation of URL facilities is expensive and so is carrying out research activities underground. Costs vary on several factors such as the depth and characteristics of the formation, the footprint of the URL and the types of R&D activities carried out. The construction cost of the Meuse/Haute-Marne URL at 570 metre depth in hard clay was 280 M€. In 2011 the facility reported an operating cost of 60 M€ per year including the costs of the R&D programme. The fact that URLs are so widely implemented despite their high costs is an indication of their value to national disposal programmes. In some countries, development of URLs is required by law (e. g., France). Other countries may prefer to collaborate with programmes in foreign URLs at least at the earlier stages in their national final disposal programme for cost sharing. For this reason, many URLs include multinational research programmes. Some URLs are part of an international training network operated by the International Atomic Energy Agency.

Example of activities at URLs

Generic URLs: Typical research and development activities conducted in **generic URLs** include: (i) development and testing of methodologies for characterizing the rock formation; (ii) techniques for excavation, construction, emplacement, and closure techniques; as well as monitoring of disturbances; (iii) experiments for understanding coupled thermal-hydraulic-mechanical-chemical processes; (iv) corrosion and radionuclide migration processes; (v) large scale experiments demonstrating the performance of engineered barrier systems at full scale (e.g FEBEX at Grimsel and EB at Mont Terri); (vi) drifts and shaft sealing tests; and (vii) development of monitoring techniques (e.g. the international programmes ESDRED and MoDeRn).

Site-specific URLs: similar activities are undertaken as those in generic URLs, but can go further and examine actual properties of the site and demonstrate feasibility, e.g., of technologies for construction, waste emplacement, operation and closure of the repository. Thus, at Äspö, Onkalo, and at the Meuse/Haute-Marne, prototype experiments are conducted such as tests of installation and performance of seals and plugs, and studies of the impact of excavation techniques on the extent of the disturbed zone. At the Meuse/Haute-Marne demonstrations of galleries lining methods in hard clay are also performed in preparation of repository construction in the same geological formation. ONKALO, which is a precursor of the final repository, has allowed data taking on excavation techniques and hydro-geological disturbances during excavation of the repository.

Recent and current research activities carried out at the URLs are often described in details on their web sites.

Opportunities at the regional and international level

Siting, construction and operation of a repository can be a favorable outcome for all involved stakeholders or a win-win project for the region where the repository is located and for the nation at large. Provisions not to impair local well being and opportunities will be created to improve quality of life durably. The economic activity in the whole region will develop from incoming staff and construction workers, a large number of visitors and increased tax revenues. The new a highly skilled resident workforce will contribute to maintain or increase the educational level of the community and will stimulate the local service economy. Involvement of the stakeholders at the local level will increase understanding of the local interests and will create new cooperation structures. The experience from the first implementations of geological repositories for high-level radioactive waste will help other national programmes move forward in a more efficient manner.

NUCLEAR WASTE REPOSITORIES TAKE DECADES TO DEVELOP. UNDERGROUND RESEARCH LABORATORIES (URLS) ARE NECESSARY FOR ACQUIRING THE TECHNICAL INFORMATION AND MANAGEMENT EXPERTISE TO ALLOW PROGRESSING FROM ONE REPOSITORY STAGE TO ANOTHER. URLS ARE LOCATED IN GEOLOGICAL ENVIRONMENTS THAT ARE SUITABLE FOR REPOSITORY IMPLEMENTATION OR THAT OFFER REALISTIC REPRODUCTION OF THOSE ENVIRONMENTS. THEY MAY BE CONSTRUCTED AT A DEPTH OF A FEW HUNDRED METERS OR ALSO CLOSER TO THE SURFACE. THERE IS NOW OVER 30 YEARS EXPERIENCE WORLDWIDE IN CONSTRUCTING AND UTILIZING URLS. GENERIC URLS HELP CREATE EXPERTISE FOR ACQUIRING TECHNICAL DATA IN A GEOLOGICAL ENVIRONMENT. THEY ARE AN EXCELLENT VENUE FOR INTERNATIONAL COOPERATION. SITE-SPECIFIC URLS HELP CREATE EXPERTISE AND ACQUIRE BOTH TECHNICAL AND OPERATIONAL DATA THAT ARE USEFUL IN SHOWING THE SAFETY AND FEASIBILITY OF A REPOSITORY IN THE SAME FORMATION OR IN A FORMATION THAT CLOSELY MIMICKS IT. MAJOR EFFORTS ARE NOW DIRECTED TOWARDS LARGE SCALE, REALISTIC, INTEGRATED EXPERIMENTS IN WHICH A NUMBER OF INTERACTING COMPONENTS AND/OR PROCESSES ARE SIMULTANEOUSLY STUDIED. URLS ARE AN IMPORTANT VENUE FOR BUILDING TECHNICAL TEAMS THAT INTEGRATE A WIDE RANGE OF SCIENTIFIC DISCIPLINES AND FOR GAINING PRACTICAL EXPERIENCE. THEY ALSO PROVIDE A VISUAL EXAMPLE OF WHAT A GEOLOGICAL REPOSITORY MAY LOOK LIKE AND CONTRIBUTE TO CONFIDENCE BUILDING BY THE GENERAL PUBLIC.