National and International Activities in the Field of Underground Disposal of Radioactive Wastes

by Dieter K Richter

Nuclear power plants and their fuel-cycle facilities generate various types of radioactive wastes, and the disposal of these wastes is an integrated part of the use of nuclear energy. With today's technology, the most feasible option to dispose of these wastes is to place them safely underground. "Underground" disposal includes the depositing of properly conditioned waste into the terrestrial subsurface in various ways, ranging from burial at shallow depths, through disposal in rock caverns at various depths, to disposal in deep continental rocks (deep geological disposal).

The safe disposal of radioactive wastes, in particular those that contain the radionuclides produced by nuclear fissioning, is also one of the main concerns of those who oppose the use of nuclear power. Disposal therefore, plays an important role in public acceptance of nuclear energy in many countries. It has often been stated that the assurance of the existence of suitable ways for the safe disposal of all kinds of radioactive wastes is a current issue which must be resolved for the further industrial development of nuclear power.

In recent years, national activities concerning the underground disposal of radioactive waste have expanded considerably in nearly all countries that are using nuclear power or are embarking on nuclear power programmes. Many countries now have significant programmes to study and investigate suitable sites and methods for waste disposal. As the crucial issue is the safe disposal of the high-level and alpha-bearing waste arising from the management of the spent nuclear fuels, most national programmes concentrate on examining the use of deep geological formations. Questions concerning radioactive waste disposal have become increasingly international in scope and are now a matter of high priority and growing importance in international collaboration.

THE WASTE DISPOSAL ISSUES

Countries that operate nuclear power plants face decisions regarding the responsibilities and arrangements for: (a) the disposal of low- and intermediate- level waste from power plant operation, (b) the disposition of the spent fuel either by delivering it back to the supplier country or another country for reprocessing, or by disposing it eventually as high-level waste, or (c) the disposal of the high-level and actinide-bearing waste from reprocessing if the reprocessing country, or another country, does not provide the disposal service. The international aspects of (b) and (c) above are evident.

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Pressure for waste disposal in many countries has been increased by the possibilities of the high-level waste being returned to them by the country that reprocesses their spent fuel, or by the need to plan for the disposal of the spent fuels themselves. Countries that, in addition to nuclear power plants, also operate spent-fuel reprocessing facilities or are planning to use the 'once through' fuel cycle must arrange for the disposal of the wastes arising from this part of the nuclear fuel cycle.

It seems to be a basic principle that a country producing radioactive waste will first have to consider the potential for disposing the waste in its own territory. The stages in planning and implementing a waste disposal policy related to a national nuclear power programme include: initial governmental and administrative decisions for underground disposal, survey of national territories, preliminary selection and confirmation of suitable repository sites; the design, construction, operation and eventual shut-down and long-term surveillance of repositories. Appropriate institutional, regulatory and financial arrangements, as well as research and development work and appropriate safety analyses, are required at each of these stages.

The objective of waste disposal is to protect the present and future population from potential hazards posed by wastes produced by the use of nuclear energy. There is also the possibility that the disposal operations may have to be carried out by institutions after the facilities that generated the waste are no longer in operation. Therefore, waste disposal is concerned with not only technical issues but also with long-term societal aspects such as the institutional, financial and legal responsibilities.

The various levels of international collaboration include exchange of information between countries on experience, practices and projects, seeking a harmonized approach by developing international guidelines and criteria, and co-operative efforts in research and development. Finally, international co-operation could mean considering waste disposal in the context of regional or international planning of the entire nuclear fuel cycle.

NATIONAL ACTIVITIES AND EXPERIENCE

Disposal of low- and intermediate-level radioactive waste at shallow depths (land burial) has been practised for decades in many countries, including Canada, France, India, UK, USA, USSR, etc The wide variety of practices employed provides considerable experience for future developments. In addition, for more than 10 years, deep geological formations have been used for the disposal of radioactive waste, mostly from nuclear research centres.

The Federal Republic of Germany has been demonstrating the disposal of solid, low- and intermediate-level waste, which is conditioned and packed in concrete or steel drums, in the former Asse salt mine since 1967. Hydraulic fracturing has been practiced since 1966 at Oak Ridge, USA, to dispose of liquid, intermediate-level waste, mixed with cement and other additives, in a shale bed at about 300 metres depth. The USSR has disposed of liquid, low- and intermediate-level waste by injecting it into deep, confined, water-bearing strata at about 1500 metres depth. Czechoslovakia and Spain are using abandoned mine galleries for the storage of packed, low-level waste.

Today, many countries are investigating the potential of underground disposal of radioactive wastes within their territories in order to establish a long-term policy. In some countries investigations are directed towards establishing central repositories for the receipt of high-level and alpha-bearing waste in the mid-1990's

The following are examples of activities in this area:

In **Austria**, the investigations concern the potential sites for waste disposal in Austrian territory and also the possibilities of obtaining the services of other countries for disposal of nuclear waste. Crystalline rock formations, especially of the Southern Bohemian massif, are being studied. An initial design has been made for a repository for the waste which is expected to be returned from foreign spent fuel reprocessing in the 1990's. Assurance of waste disposal is a condition for operating the first Austrian nuclear power station.

In **Belgium** and **Italy**, the utility of argillaceous (clayey) formations for waste disposal is being investigated. In Belgium, prospecting and laboratory investigations of the properties of a clay bed near Mol are under way Studies also concern radionuclide migration, heating experiments, and conceptual design, including underground excavations in the clay bed. Field tests in an experimental cavern will also be carried out. Similar studies in Italy concentrate on theoretical studies and laboratory tests, and deal with the hydro-geological, geotechnical and thermal characteristics of clay formations in an area in southern Italy.

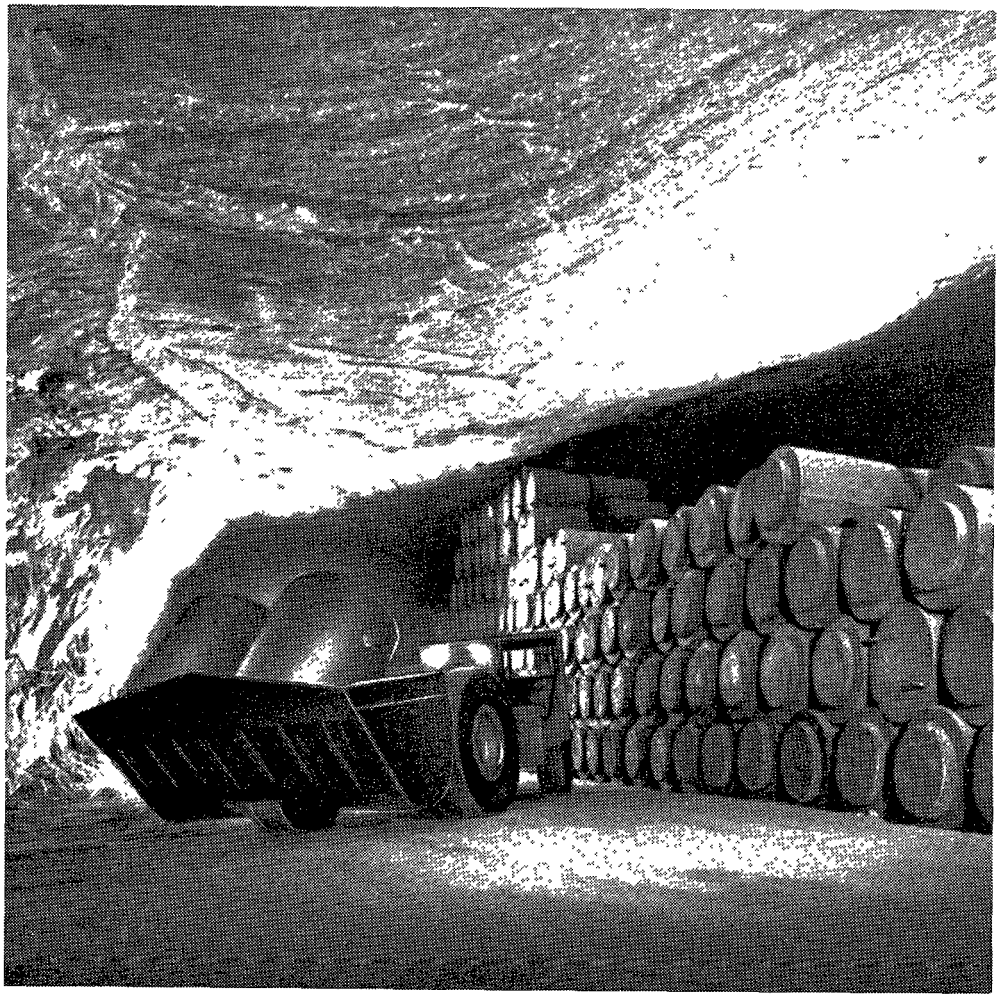
Canada is exploring the potential of the plutons (large bodies of igneous rock) in the Canadian Shield for waste repositories. Salt formations are also being studied. The programme covers geological reconnaissance, conceptual design and engineering for a model repository Laboratory and field tests being carried out include heating experiments in a part of an operating mine and studies on groundwater behaviour.

Czechoslovakia has surveyed its territory to select a repository at shallow depth for low- and intermediate-waste from nuclear power plant operations. For high-level waste disposal, interest is focused on the use of crystalline rocks.

Activities in **France** concentrate on the potential for waste disposal in crystalline rocks, in particular, granite. Consideration is also given to the possibilities of waste disposal in salt, shale or clay. The characteristics of deep granite formations are being studied. Investigations also include the modelling of radionuclide transfer by groundwater, for which a mathematical model has been developed, and studies of geochemical barriers such as layers of clay.

In the **German Democratic Republic** the potential for radioactive waste disposal on its territory was studied and a former salt mine was selected for adaptation as a central repository for the disposal of low- and intermediate-level waste from nuclear power plant operations. The problems connected with the disposal of high-level waste into rock salt are also being examined.

The **Federal Republic of Germany** has been using the former Asse salt mine as a research and development facility. Preparations for test disposal of solidified, high-level waste are under way. The research programme includes a rock cavern project at the Asse salt mine for demonstrating the emplacement of low- and intermediate-level waste directly from the surface into a large deep underground cavity. Research also covers theoretical, laboratory and field investigations concerning heat dissipation and rock mechanics, risk analysis, repository design, the storage of conditioned spent-fuel elements from the AVR reactor, and investigations on the possibilities of in-situ solidification of liquid low- and intermediate-level waste Reconnaissance work has been carried out at several salt domes in the northern part of the country for a potential repository that could take the waste from a fuel cycle centre planned for the late 1980's. The suitability of a specific site is currently being investigated.



Methods and technologies for the disposal of radioactive wastes are proved at the former Asse salt mine in the Federal Republic of Germany. Photo GSF mbH

In **India** various geological formations are being evaluated, in particular, igneous rocks and selected sedimentary deposits in non-seismic zones. Detailed site investigations are expected to follow.

In **The Netherlands,** the possibilites of waste disposal in one of the salt domes in the north-eastern part of the country are being explored. Work is being carried out on repository design, thermal impacts and safety assessment, including sorption studies in saline groundwater.

In **Sweden** an all-out effort was devoted to meet the requirements of a law passed in 1977. The law sets out conditions for establishing any new nuclear power plant. The conditions require the reactor operator to have a contract providing for the reprocessing of spent fuel and to demonstrate how and where the final deposition (disposal) of the highly radioactive

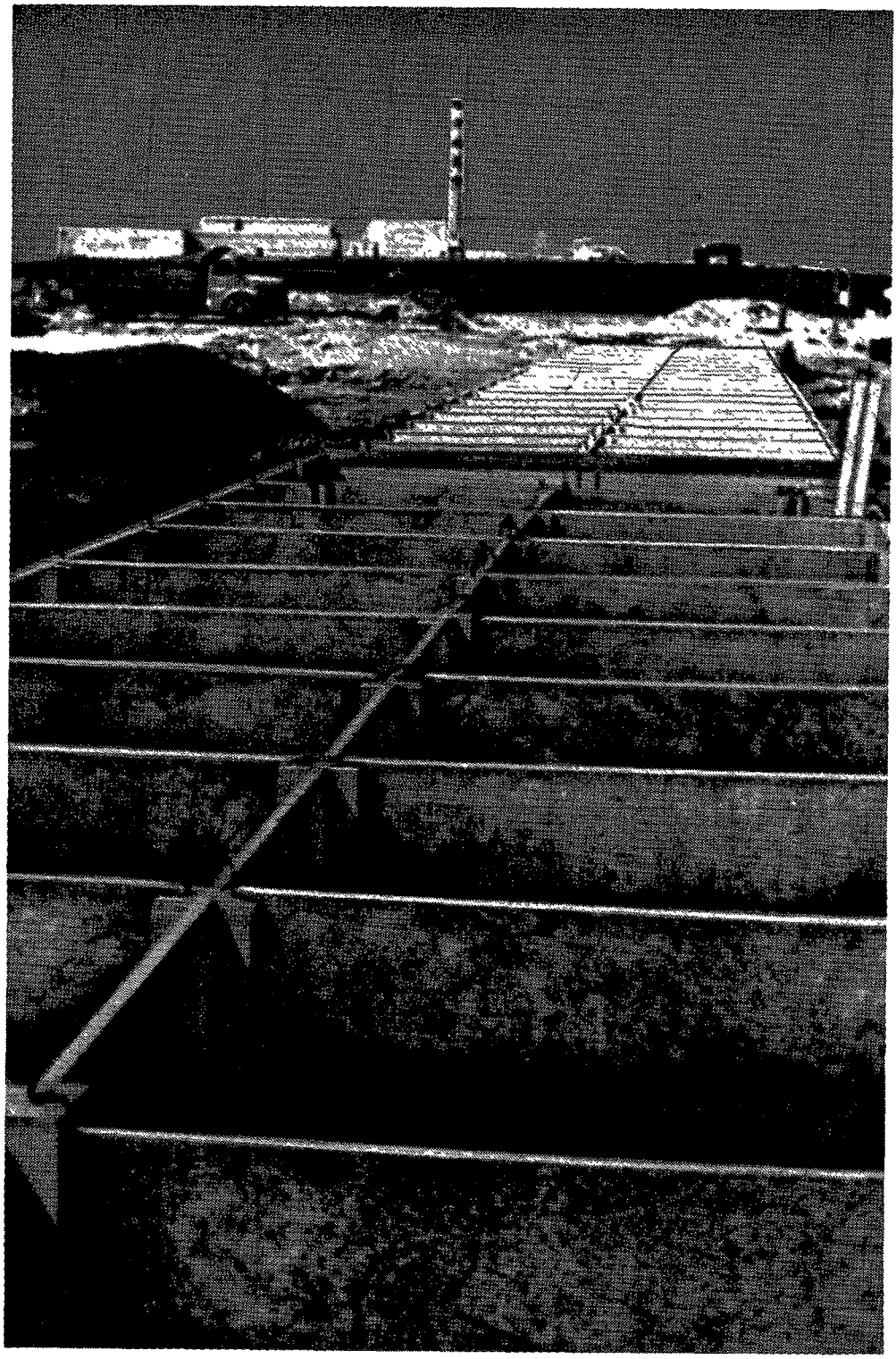
waste resulting from reprocessing the fuel can be accomplished with 'absolute' safety As a result of the law, besides long-term studies sponsored by the Government, the Swedish utility companies started a special project "Nuclear Fuel Safety" (KBS) to demonstrate the possibilities of disposing high-level waste and/or spent fuels in a deep geological repository in crystalline rocks. The work encompasses area survey, hydro-geological site investigations and field tests, mechanical and hydrological characteristics of the rock, special investigations on low groundwater flow and radionuclide migration in fractured rocks, conditioning and emplacement techniques, repository design and safety analyses. The project also includes field tests of a granite formation in the former Stripa iron mine in central Sweden, where in-situ heater experiments and special hydro-geological investigations are being performed

In **Switzerland** studies concern the potential of anhydrite caverns for the disposal of low- and intermediate-level waste, and the possibility of high-level waste disposal in certain salt or crystalline basement rocks.

In the **United Kingdom** research is being carried out on the suitability of crystalline rocks for the disposal of high-level waste and, to a lesser extent, on argillaceous and salt formations. The research efforts encompass laboratory and theoretical studies of rock and groundwater behaviour, interim field studies at sites having equivalent characteristics to those which eventually may prove suitable, and actual site investigations. They involve fluid/rock and fluid/waste interactions, groundwater research, modelling of thermal stressing and scaled heater experiments, repository design studies, detailed surface and sub-surface geological surveying

The **USA** initiated a National Waste Terminal Storage Programme in 1976 under the direction of US ERDA (now incorporated into the Department of Energy). The programme covers identification of suitable rock formations for waste disposal, reconnaissance studies, in-situ tests, field area and detailed field confirmation studies, and the establishment of several (up to six) central federal repositories Work concerning salt formations is most advanced since it benefits from earlier experience. Previous investigations of this topic include 'Project Salt Vault' in the 1960's which consisted of pilot plant tests simulating the emplacement of high-level waste in a bedded salt mine. A Waste Isolation Pilot Plant (WIPP) is currently under study. This repository is planned for the receipt of radioactive waste from the military programme in the mid-1980's and its expected location is a bedded salt formation in New Mexico. It is later planned to establish other federal repositories for the disposal of waste from the commercial nuclear power programme, including the disposal of spent fuel should the United States decide on the once-through fuel cycle. These plans imply a search for two sites in salt formations and for several other sites in other types of formations, possibly in shale and crystalline rocks (volcanic basalt). Investigations of non-salt formations are being carried out at the Nevada test site near Las Vegas and the Hanford site near Richland, Washington Consideration is also given to the use of other methods for deep geological disposal, such as injection of fluids into isolated porous strata or into induced fractures in impermeable formations. The radioactive waste repositories are to be licensed by the US Nuclear Regulatory Commission (NRC), and the NRC is drawing up the necessary associated regulatory framework and criteria.

Shallow ground burial of low activity waste at La Hague. Photo CEA, France. ▶



The **USSR** has been studying the technical, geological, hydrological physico-chemical, and thermal aspects connected with the disposal of low-, intermediate- and high-level liquid waste by injection into deep, isolated porous strata. Comprehensive field experience is available and tests for the injection of high-level liquid waste have been performed. Research and development work is also being done on the disposal of solidified high-level waste. It includes investigations and field experiments of long-term storage in engineered, dry-storage facilities at shallow depths, and studies of the use of deep, continental rocks, in particular, of salt formations.

INTERNATIONAL EXCHANGE OF INFORMATION AND COLLABORATION IN RESEARCH AND DEVELOPMENT

International conferences or symposia have encouraged exchange of information on practices, experience and projects on underground disposal of radioactive waste and its associated scientific and technical aspects. Such conferences were held by the IAEA, the Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development (OECD), the Commission of the European Communities (CEC), the Council of Mutual Economic Assistance (CMEA) and by other international associations and national authorities[1].

To meet the great interest in this area, the IAEA will convene, jointly with OECD/NEA, an International Symposium on the Underground Disposal of Radioactive Waste, which will be held in Otaniemi near Helsinki, Finland, in July 1979.

In addition, several multinational organizations have established programmes for co-ordinating national research and development activities, including exchange of information.

The **Nuclear Energy Agency of the OECD** indicated disposal of high-level and alpha-bearing waste in deep geological formations as a high priority area for co-operation among its Member States and established in 1975 a standing Co-ordinating Group on Geological Disposal under its Radioactive Waste Management Committee. The Co-ordinating Group meets once a year to exchange information on the status of national research and development programmes and to initiate closer forms of co-operation between interested countries. One aspect of its work is to organize workshops on specific topics, such as the joint NEA/CEC workshop on Risk Analysis and Geologic Modelling in Relation to the Disposal of Radioactive

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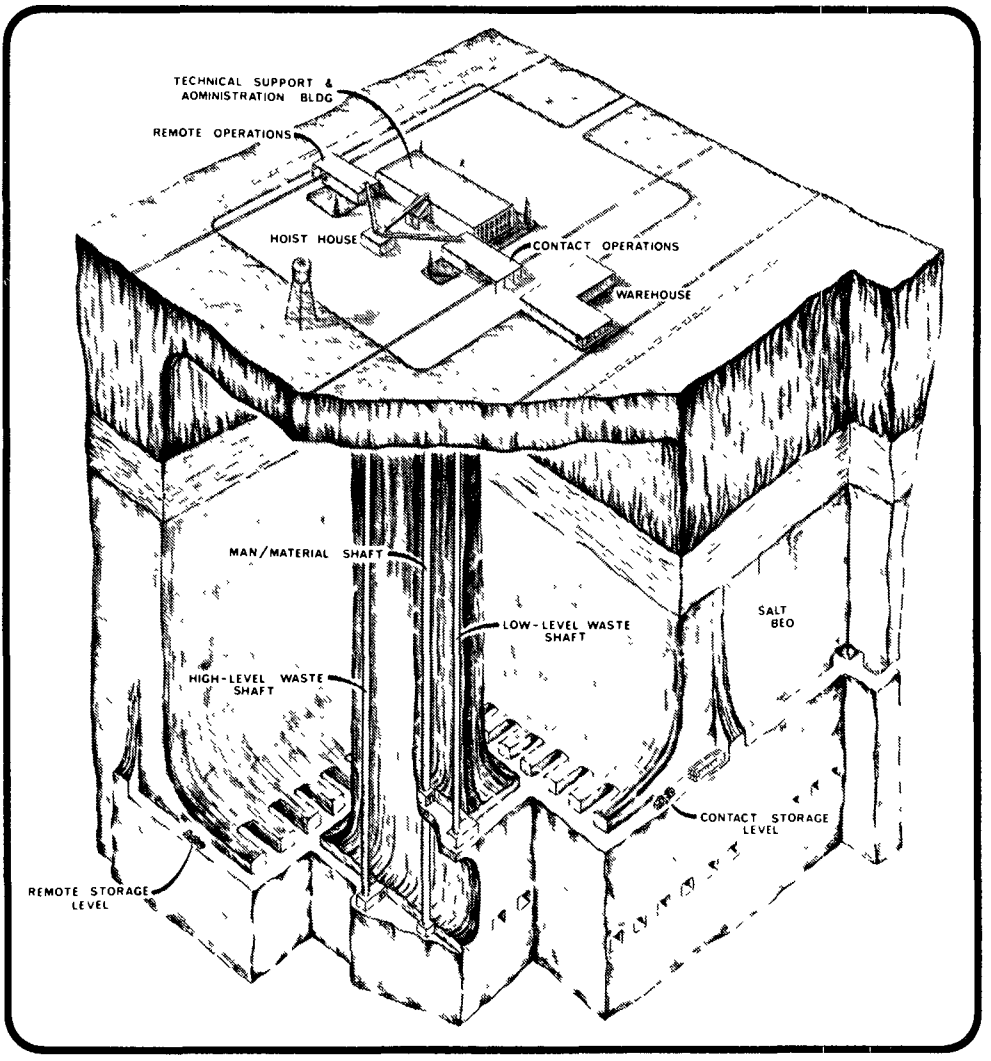
[1] The most important are
IAEA/ENEA Symposium on the Disposal of Radioactive Waste into the Ground, Vienna, 1967,
IAEA/ENEA Symposium on the Management of Low- and Intermediate-Level Radioactive Waste, Aix-en-Provence, France, 1970,
NEA/IAEA Symposium on Management of Radioactive Waste from Fuel Reprocessing, Paris, 1972,
IAEA/NEA Symposium on the Management of Radioactive Waste from Nuclear Fuel Cycle, Vienna, March 1976,
IAEA Conference on Nuclear Power and its Fuel Cycle, May 1977, Salzburg, Austria,
NEA-Seminar on the Disposal of Radioactive Waste into Geological Formations, December 1975, Clausthal-Zellerfeld, FRG,
USA International Symposium on the Management of Radioactive Waste from the LWR Fuel Cycle, July 1976, Denver, USA
First International Symposium on the Storage in Excavated Rock Caverns, Rockstore 77, September 1977, Stockholm, Sweden,
CMEA Conferences on the Treatment and Disposal of Radioactive Waste and the Decontamination of Surfaces, 1967, Dresden, GDR, 1972 at Kolobczeg, Poland, and 1976 in Moscow, USSR.

Concrete pits for ground disposal of low activity waste at La Hague Photo CEA, France.

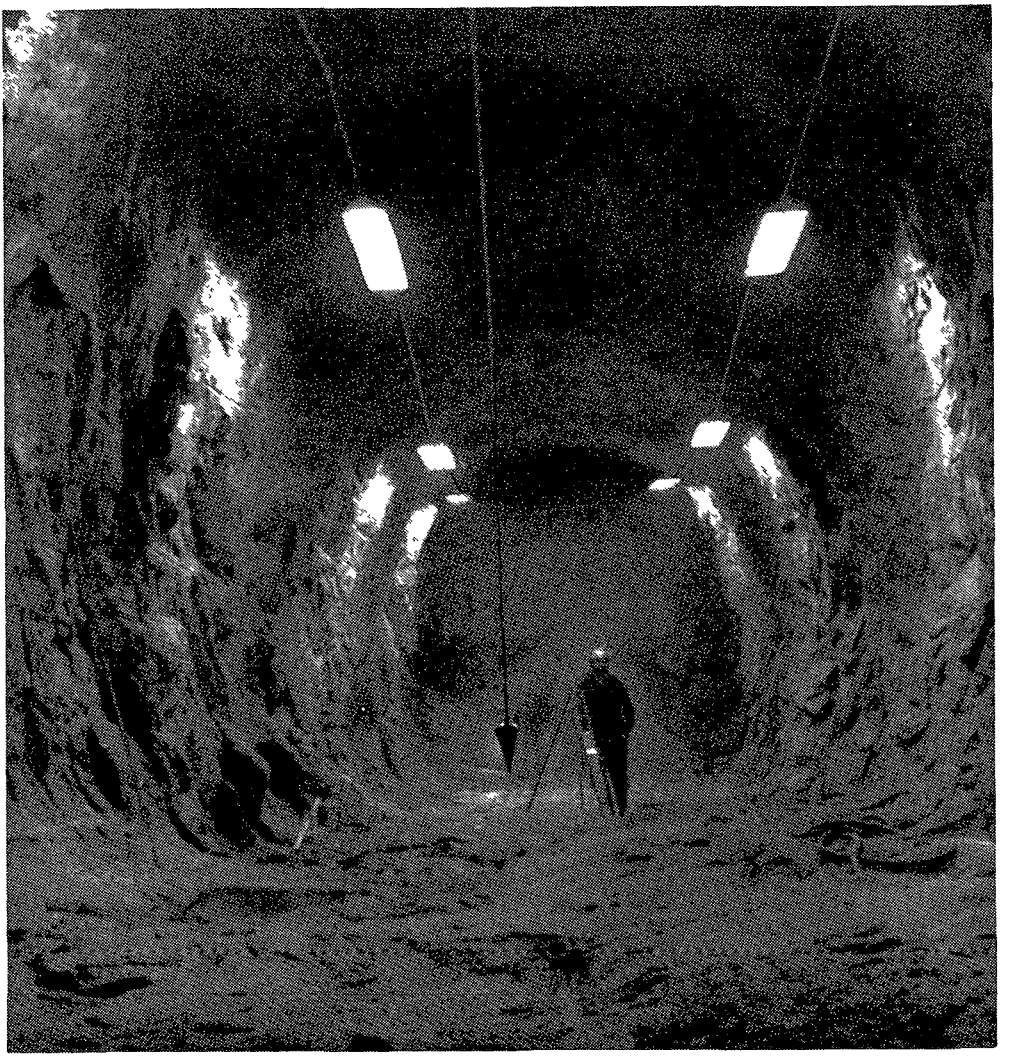
Waste into Geological Formations. This was held in May 1977 at the CEC Research Establishment Ispra, Italy. Further workshops are planned to deal with in-situ heating experiments, and low-flow and low-permeability measurements in largely impermeable rocks. Another example of NEA's activities relevant to geological waste disposal is the experts report on "Objectives, Concepts and Strategies for the Management of Radioactive Wastes arising from Nuclear Power Programmes", which was published in September 1977. NEA is seeking to obtain, as soon as possible, sufficient information to confirm and demonstrate the applicability of various disposal systems in different rock formations.

The **Commission of the European Communities (CEC)** work on deep geological disposal of high level and alpha-bearing waste is carried out on a shared-cost basis by institutions of member countries, as well as in CEC laboratories, for example the Ispra Research Establishment which evaluates long-term hazards. The main objective of the CEC's work is to initiate the



Deep underground disposal of high-level nuclear waste effectively isolates the waste for hundreds of thousands of years. Several different concepts for final disposal of HLW have been developed Shown here is a simplified cutaway of a disposal site in a geologically stable salt or rock formation.

establishment of repositories in different rock types for demonstration purposes. Under a five year programme (1975–1979), the CEC is contributing around 40% to the cost of research and development projects pertaining to geological disposal within its Member States. Work under contract from the CEC is being done on the use of salt formation in the Federal Republic of Germany and the Netherlands, on argillaceous formations in Belgium and Italy, and on crystalline rock in France and the UK. The activities of CEC include the compilation of a catalogue of geological formations which may be of potential interest for its member countries. The CEC programme also includes geological investigations, scientific and technical support studies, engineering studies and risk analysis and considers the legal, administrative and financial aspects involved.



The former Stripa iron ore mine in Sweden has been selected as the site for a joint Swedish-American project to test the suitability of granite for storage of nuclear waste The mine's underground tunnels form a labyrinthine maze and the photo shows one of these tunnels being surveyed. Photo AB Atomenergi Sweden.

The **Council of Mutual Economic Assistance (CMEA)** established a Co-ordinating Scientific Council on waste management and decontamination in 1971. This is part of the CMEA Standing Committee on the Peaceful Uses of Atomic Energy, whose programme includes research on the disposal of waste in geological formations. Some documents have been prepared detailing the investigations necessary to justify the suitability of a site for the deep well injection of liquid waste, the use of salt formations and waste burial at shallow depths.

ACTIVITIES OF THE IAEA

The IAEA initiated its work on underground disposal of radioactive waste in 1962 by convening a panel meeting. This resulted in the Safety Report Series No.15, 'Radioactive Waste

Disposal into the Ground', issued in 1965. Since that time, consideration of underground disposal has been included in several IAEA symposia and meetings.

The objective of the Agency's underground disposal programme is to review and disseminate information on the subject; to establish safety standards and recommendations which eventually may take the form of codes and guides, to promote exchange of results from national and multinational research programmes, to sponsor research work in appropriate fields and to provide technical assistance upon request.

An Advisory Group on radioactive waste disposal into geological formations met in early 1978 and recommended that the IAEA initiate a long-term programme with emphasis on developing internationally acceptable guidelines and criteria in this field.

The programme should encompass all the techniques and options presently under investigation in Member States or other international organizations, such as

- emplacement of solid or solidified high-, medium- and low-level and alpha-bearing waste into deep geological formations (e.g crystalline rocks, rock salt, clay and shale)
- emplacement of solid or solidified low- and medium-level and alpha-bearing waste into (existing) rock caverns at various depths
- emplacement of solid or solidified low-medium level waste at shallow depths (shallow land burial)
- deep well injection of liquid/gaseous waste into isolated porous strata
- injection of fluid waste (waste/grout mixtures) into induced fractures within impermeable formations.

GUIDELINES AND CRITERIA

On the recommendations of the Advisory Group, the IAEA is planning to develop guidelines and criteria on the safe underground disposal of radioactive waste over the next several years. The documentation to be developed covers various disposal options, ranging from deep geological disposal to shallow land burial, and includes five major areas

1) Regulatory activities (approval procedures, principles and assessment methods)
2) Siting (site selection factors, site investigations)
3) Waste acceptance criteria
4) Design and construction
5) Operation and shut down of repositories.

Work will include the preparation of technical reports, which will be followed, when the subject is sufficiently advanced, by the preparation of guides and codes.

The IAEA began its activities in this area with its report on "Site Selection Factors for Repositories of Solid, High-Level and Alpha-Bearing Waste in Geological Formations", which was published as IAEA Technical Report No.177 in 1977. Documents currently under development include: "Correlation of Waste Type and Ground Disposal Technique", "A Guide to Shallow Land Burial", and "Approval Procedures for Disposal of Solid Waste in Deep Continental Rocks". Publication of these reports is planned in 1979. They are expected to be followed by documents describing the investigations necessary to select and confirm the suitability of a site for various disposal options, as well as regulatory principles and assessment methods for underground disposal.

REGIONAL REPOSITORIES AND DEMONSTRATION PROJECTS

The concept of regional waste repositories has attracted interest as a way of meeting the radioactive waste disposal needs of a group of countries, particularly those not having favourable geological and hydrological conditions. In addition, high interest has been expressed in establishing an international facility for demonstrating the disposal of high-level and alpha-bearing waste in deep geological formations. The question of international co-operation in this field keeps being raised.

Waste disposal may also be considered as part of a regional or international planning of the nuclear fuel cycle. This would be of particular interest to countries having relatively small reactor power programmes. The IAEA discussed the co-location of waste repositories and regional reprocessing plants in its Study Project on Regional Fuel Cycle Centers (RFCC) published in 1977. The RFCC Study can be regarded as providing a basis for interested countries to study the possibilities of joint international action in this area. Also, the International Nuclear Fuel Cycle Evaluation (INFCE), a multinational project initiated by the USA to study non-proliferation aspects of different nuclear fuel cycle strategies, may consider all the various aspects of waste disposal.