

IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety



Radioactive waste management

Collecting, sorting, treating,
interim storage and final
disposal for our protection.

The generation of electricity, but also hospitals, universities and specific non-nuclear industries produce radioactive waste. All of the regulations specific to waste in general apply to radioactive waste.

But radioactive waste emits radiation and is therefore a specific hazard for human health.

It should therefore be managed with special care, from its production to its final destination.

The creation of suitable waste disposal systems constitutes a major challenge for all players present, manufacturers, regulatory authorities, public authorities, local communities and the population.



Fuel assembly.



Radioactive waste management and disposal

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1

What is radioactive waste?

Radioactive waste is radioactive substances for which no further use is foreseen or planned.

A radioactive substance is any substance containing natural or artificial radionuclides, the activity or concentration of which warrants a radiation protection inspection.

Final radioactive waste is radioactive waste which can no longer be treated under the technical and economic conditions of the moment, notably by the extraction of the reusable part or by the reduction of its pollutant or hazardous character (French Environmental Code, Article L 542.1-1).

The radionuclides contained in radioactive waste may be artificial, such as caesium 137, or natural, such as radium 226.

The radioactive characteristics of waste include:

- the type of radionuclides contained and the radiation emitted (alpha, beta, gamma), the activity (number of atom nuclei which spontaneously disintegrate per unit time - expressed in Becquerel),
- the radioactive half-life (time required for half the atoms of a radionuclide in a sample to disappear).



Containers of waste, vitrified on the left and compacted on the right.

Most radioactive waste is produced by the nuclear power industry. The remainder is produced by the use of radioelements in hospitals, universities

and specific non-nuclear industries, and by national security-related activities.

□ Their classification

Radioactive waste is classified according to its activity and the "radioactive half-life" of the radionuclides that it contains. The level of radioactivity determines the importance of the protection to be implemented. A distinction is therefore made between very low, low, medium or high-level

waste. Radioactive waste is said to be "short lived" if it only contains radionuclides with a half-life less than 31 years.

Radioactive waste is said to be "long lived" if it contains a significant quantity of radionuclides with a half-life greater than 31 years.

Radionuclide	Half-life
Cobalt 60	5.2 years
Tritium	12.2 years
Strontium 90	28.1 years
Caesium 137	30 years
Americium 241	432 years
Radium 226	1,600 years
Carbon 14	5,730 years
Plutonium 239	24,110 years
Neptunium 237	2,140,000 years
Iodine 129	15,700,000 years
Uranium 238	4,470,000,000 years

Therefore, there are several categories of waste:

- **very short lived waste (VSLW)** a significant part of which is generated by medical radioactivity applications (diagnostic or therapeutic purposes) and the radioelements of which have a half-life less than 100 days;
- **very low-level waste (VLLW)** which is produced by the nuclear power industry, in particular nuclear facility dismantling operations. Uranium ore treatment residues may come under this category: they receive special management;
- **short lived low and medium-level waste (LMLW-SL)** which mainly comes from the nuclear power industry, but also from some research laboratories;
- **long lived low-level waste (LLW-LL)** which is either radium-contaminated (known

as "radiferous") waste and which mostly comes from the use of naturally radioactive raw materials in industrial processes, the recovery of "radium-bearing" objects, the clean-up of contaminated sites, or "graphite" waste which comes from the dismantling of former French "natural uranium graphite gas" reactors;

- **long lived medium-level waste (MLW-LL)** which mostly results from the treatment of spent fuel (spent fuel cladding, sludge from the treatment, etc.) and from the maintenance of nuclear facilities;
- **long lived high-level waste (HLW-LL)** which includes materials that cannot be recycled produced by the treatment of spent fuels in nuclear power plants.



Dismantling operations (VLLW).



Rare earths (LLW-SL).



Solid waste in its concrete drums, before covering with cement.



Concrete covering.

□ A management method for each category of waste

Radioactive waste has a high degree of diversity depending on its physical and chemical form, its radioactivity and the half-life of the radionuclides involved, but also depending on its volume. In France, each category of waste is managed in a specific system comprising a series of operations such as sorting, treatment, conditioning, interim storage and disposal.

Sorting: enables the waste to be separated according to its characteristics, in particular, the radioactive half-life of the radionuclides that it contains. It also results in the separation

of waste that can be compacted, incinerated or melted down.

Treatment and conditioning: depending on its nature, waste undergoes different treatments (incineration, calcination, fusion, compacting, cementation, vitrification, etc.). It is then sealed in a container. This produces an object known as a radioactive waste “package”.

Interim storage and disposal: interim storage facilities are designed to receive waste packages for a limited period. Disposal is the final stage of a waste management system



VLLW waste includes rubble, scrap and pipes mainly from dismantled nuclear facilities.

and presumes final disposal of packages or, at least, no intention of retrieving them.

This, of course, means that the provisions retained guarantee short-term and very long-term protection for humans and for the environment.

Very short lived waste (VSLW), the level of radioactivity of which disappears almost entirely in a few tens to a few hundreds of days, is stored long enough to decay before waste disposal (in particular hospital waste system).

Very low-level waste (VLLW) is stored in a waste disposal facility located in Morvilliers (Aube) and operated by Andra. The total volume of waste after dismantling a nuclear power plant is estimated to be 1 to 2 million m³. Residues from the treatment of uranium ores belong to this category but are managed in a different way. All uranium mines in France are now

closed. The residues are stored on approximately twenty mining sites, under Areva's responsibility. They represent a volume of around 52 million tonnes of material.

Short lived low and medium-level waste (LMLW-SL, also known as LLML or "A" waste) is incinerated, melted down, covered or compacted. Most of the time it is cemented in metal or concrete containers. It is stored in two surface disposal facilities: la Manche facility, closed since 1994 because it had reached its nominal capacity of 527,000 m³, and the Aube facility, opened in 1992 and operated by Andra.

It is estimated that the volume of this waste will reach approximately 1.3 million m³ at the end of the operating life of the nuclear power facilities currently in operation (retaining the assumption of 40 years of reactor operation then their dismantling).



Drum compaction.

Long lived low-level waste (LLW-LL) is stored by producers pending a waste disposal solution, for which the search for a location has begun. It represents approximately 4.5% of the overall volume of waste (and 0.01% of the radioactivity).

Long lived medium-level waste (MLW-LL, also known as "B" waste) is compacted or cemented, and therefore forms packages which are stored on their production site. It represents approximately 5% of the overall volume of radioactive waste and 4% of the radioactivity.

Long lived high-level waste (HLW-LL, also known as "C" waste) is vitrified; this involves incorporating highly radioactive waste into a fusion glass.



Fusion of metal waste.

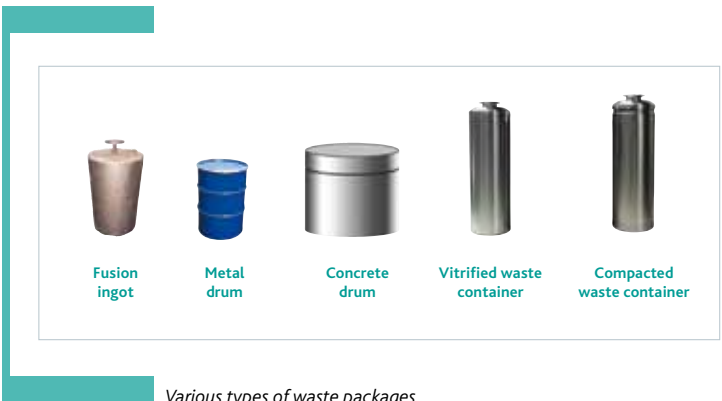
After cooling, the radioactivity is trapped in the glass matrix. It is poured into stainless steel containers and then hermetically sealed by welding a lid. These waste packages are currently stored by producers (CEA, Areva) on their past (Marcoule, Gard) or present (La Hague, Manche) production sites. They represent approximately 0.2% of the overall volume of waste and 96% of the radioactivity.

The interim storage of long lived medium-level waste (MLW-LL) and long lived high-level waste (HLW-LL). Considering past nuclear activities and spent fuel treatment scenarios, the volume of long lived medium-level waste would reach approximately 80,000 m³ in 2020. The volume of long lived high-level waste would represent 8,000 m³.



Interim storage of waste in a hall of the Brennilis power plant (EDF).

Spent fuels, which in particular contain uranium and plutonium that can be recovered and recycled, are stored in pits in Areva's La Hague power plant for cooling before "prompt" (within five to ten years) or deferred reprocessing (pending a use for the plutonium that they contain).



Various types of waste packages.

Management solutions developed within the framework of the PNGMDR* for the various categories of waste

Half-life	Very short lived (less than 100 days)	Short lived (less than 31 years)	Long lived (greater than 31 years)
Very low-level waste	Radioactive decay management	Surface dedicated disposal. Recycling systems (activity < 100Bq/g).	
Low-level waste		Surface disposal facility (waste disposal facility in the Aube)	Subsurface dedicated disposal (under consideration)
Medium-level waste			
High-level waste		Systems under consideration within the framework of Article 3 of the Programme Act of 28 June 2006 relating to the sustainable management of radioactive waste and materials	

* Spent fuel transport package and interim storage equipment.



In the Aube Centre (Andra), packages are deposited in "disposal structures", which are concrete compartments. Once filled, the compartments are covered with a concrete slab and a polyurethane membrane.



How is long lived waste managed?

Three avenues of research (also called “fields”) were retained by the Act of 30 December 1991 relating to the future of long lived high-level radioactive waste: separation-transmutation (field 1), disposal in deep geological formations (field 2), conditioning and long-term interim surface storage (field 3). CEA led the research for fields 1 and 3 and Andra for field 2. Based on the research results obtained, a new Act, published in 2006, arranged the continuation of the process for managing this waste.

The new Programme Act 2006-739 relating to the sustainable management of radioactive waste and materials was adopted on 28 June 2006. It particularly stipulates that:

- the sustainable management of any type of radioactive waste and materials, resulting namely from the operation or dismantling of facilities using radioactive materials or sources, is provided while respecting the protection of the health of people, safety and the environment;
- the research and implementation of equipment required for making radioactive waste

ultimately safe are undertaken to prevent or limit the burden that would be supported by future generations; producers of spent fuels and radioactive waste are responsible for these substances.

The Act institutes a national radioactive materials and waste management plan (PNGMDR) and defines deadlines for the main stages and their management. A national commission is responsible for evaluating the state of progress of the research and studies relating to the management of radioactive materials and waste on an annual basis in view of the objectives set by the above-mentioned plan. Decree 2008-357 stipulates the requirements relating to this plan (see notably the table of management solutions presented in p. 12).

This plan must therefore respect the following objectives:

- the reduction of the quantity and harmfulness of radioactive waste is particularly sought via the treatment of spent fuels and the treatment and conditioning of radioactive waste;

■ the radioactive materials awaiting treatment and the final radioactive waste awaiting disposal are stored in facilities specially designed for this purpose; after interim storage, the final radioactive waste that cannot be stored in surface or near-surface facilities, due to nuclear safety or radiation protection reasons, are

disposed of in deep geological formations.

In the case of long lived medium or high-level waste, the 2006 Act stipulates that the research and studies relating to this waste shall be pursued according to the following three complementary fields.

□ Separation and transmutation

Principle

The aim of separation and transmutation is to reduce the quantities of long lived radioelements contained in the final waste by separating them using chemical processes then by transmuting them under neutron flux, i.e. transforming them into short lived elements.

State of the researchs

Research has confirmed that the aim of separation-transmutation is very ambitious.

Separation is a complex extension of reprocessing. It may be envisaged for future plants, but may only concern specific long lived waste. Transmutation presumes the development of new facilities (reactors, dedicated

particle accelerators) and may only be envisaged through sustainable programmes spanning hundreds of years.

Moreover, although transmutation is able to destroy some separated long lived elements (actinides), it is without a doubt very difficult, or even impossible, to apply to other elements such as long-lived fission products. In addition, some of these fission products are more mobile in disposal situations because they are soluble and liable to move with groundwater. Separation-transmutation in itself therefore does not appear to be an alternative technique to geological disposal.

Order of magnitude of the volumes of radioactive waste produced

extracted from the report The bars of the mission on the meth...

WASTE TYPES	QUANTITIES
RUBBLE AND SCRAP FROM DISMANTLED NUCLEAR FACILITIES (VERY LOW-LEVEL WASTE, VLLW).	1 to 2 million m ³ or more
ORE TREATMENT RESIDUES (RADIFEROUS WASTE) FROM CHEMICAL ACTIVITIES AND OLD CONTAMINATED SITES.	100,000 m ³ or more
URANIUM ORE TREATMENT RESIDUES FROM URANIUM PRODUCTION.	52 million tonnes
FILTERS, USED EQUIPMENT, OVERALLS, GLOVES, ETC., FROM POWER PLANTS AND REPROCESSING PLANTS. (SHORT LIVED LOW AND MEDIUM-LEVEL WASTE) USED SOURCES FROM HOSPITALS AND INDUSTRY.	1.3 million m ³
TRITIATED WASTE FROM THE MANUFACTURING OF NUCLEAR WEAPONS (MILITARY APPLICATIONS DIVISION - CEA).	3,500 m ³
GRAPHITE WASTE FROM FIRST GENERATION "GRAPHITE-GAS" NUCLEAR POWER PLANTS CURRENTLY SHUT DOWN.	14,000 m ³
LIQUID WASTE TREATMENT SLUDGE. WASTE PACKAGES FROM THE OPERATION OF RESEARCH CENTRES AND THE RECOVERY OF OLD WASTE. METAL FUEL STRUCTURES FROM THE REPROCESSING OF SPENT FUELS. USED SOURCES (LONG LIVED MEDIUM-LEVEL WASTE).	60,000 m ³ (*)
VITRIFIED FISSION PRODUCTS FROM THE REPROCESSING OF SPENT FUELS (LONG LIVED HIGH-LEVEL WASTE).	5,000 m ³ (*)
UNTREATED SPENT FUELS (LONG LIVED HIGH-LEVEL WASTE).	3,500 tonnes (*)

(*) Assuming that all fuels are reprocessed, except for MOX fuels and reprocessed uranium fuels.

and to be produced up to the end-of-life of the existing facilities,
Methodology for the inventory of radioactive waste (Source ANDRA).

WHICH SYSTEMS?

Sorting and interim bulk storage by producers (EDF, AREVA, CEA).
 Surface disposal in the planning stage by ANDRA.

Decontamination of contaminated sites and interim storage on production sites.
 Disposal concept under consideration by ANDRA.

Redevelopment of sites by AREVA (22 sites).
 On-site disposal by AREVA.

Sorting, treatment and conditioning by manufacturers (EDF, AREVA, CEA, SOCODEI)
 and by ANDRA for the small producers (hospitals, universities, etc.).
 Surface disposal by ANDRA.

Interim storage by CEA on production sites.
 Management systems under consideration.

Treatment, conditioning and interim storage by CEA and AREVA.
 Management method under consideration (Act of 30 December 1991).

Treatment, conditioning and interim storage (in ventilated shafts) by AREVA.
 Management method under consideration (Act of 30 December 1991).

Treatment, conditioning and interim storage (in ventilated shafts) by AREVA.
 Management method under consideration (Act of 30 December 1991).

Interim storage (in pits) by EDF and AREVA.
 Pending management method.

The 2006 Act stipulates that research shall be pursued on the separation and transmutation of long lived radioelements. The corresponding research and studies shall be conducted in relation to those performed on the new generation nuclear reactors (see Article 5 of the Programme Act no. 2005-781 of 13 July 2005

defining the guidelines of the energy policy) and on the accelerator-driven reactors devoted to the transmutation of waste. The objective stipulated by the Act is to have an assessment made in 2012 of the industrial prospects for these reactors and a prototype installation in operation before the end of 2020.



XXXXXXXXXX
xxxxxx
Xxxx

□ Reversible disposal in deep geological formations

Principle

This involves depositing waste packages in underground structures dug in an impermeable geological environment with favourable characteristics in terms of its geochemical, hydrogeological and geological stability and behaviour to mechanical and thermal stresses.

The environment must be chosen so as to avoid areas that are exceptionally important in terms of underground resources that can be extracted and the structures must be located at least 200 m deep in order to avoid any repercussions relating to erosion and human intrusions.

The 2006 Act defines disposal in deep geological formations as a sustainable management solution while establishing the principle of its reversibility. An Act shall notably define, as a precautionary measure, the minimum period during which the reversibility of such disposal must be guaranteed. This period may be no less than one hundred years.

The geological disposal concepts studied are based on the multiple barrier principle which prevents the arrival of water on the waste then the dispersion of radioactive substances. These barriers include the waste package, the "structured barrier", which is the manufactured material that may be placed between the waste package and the bedrock, and the geological barrier which is the bedrock itself. The role of the host geological environment is more specifically to contain the radioactive substances released over time guaranteeing very slow migration and favouring the retention phenomena in the terrain passed through, in order to benefit from radioactive decay.

The Programme Act of 28 June 2006 stipulates for 2015 instruction of the license application to construct such a disposal facility. Subject to this license, the facility shall be placed in operation in 2025.

□ Interim storage

Principle

Interim storage is the operation where radioactive waste is temporarily placed in a surface or near-surface facility that is specifically designed for this purpose, pending its retrieval, in view of its treatment or evacuation to dedicated management systems. It is justified in particular for waste, the related systems of which are in the process of being studied. Industrial interim storage facilities now exist on nuclear sites.

Interim storage safety

The design of interim storage facilities must combine robustness and simplicity and respect

the radiation protection and safety principles usually implemented for nuclear facilities. By definition, interim storage is temporary, therefore all of the packages must be monitored so that they can be retrieved under easy and safe conditions.

The 2006 Act requires the corresponding research and studies to be conducted, at the latest by 2015, in view of creating new interim storage facilities or modifying the existing facilities in order to meet the requirements (capacity, duration, etc.) listed in the PNGMDR.



Interim vitrified waste storage. View from above the shafts (Marcoule).

3

Disposal in deep geological formations worldwide

Disposal in deep geological formations is currently considered by most countries as the reference solution for the final management of long lived medium or high-level waste. The topic is the subject of regular and relatively intensive discussions worldwide.

These discussions particularly aim to highlight common technical principles, organise the sharing of experiences, and also share the research effort. In particular, they are part of the work initiated by the NEA/OECD*, the IAEA** and the European Commission***.

The countries that have large nuclear power plants are among the most active worldwide. This is particularly the case of the United States, Canada, Japan, China and Korea, and in Europe, Germany, Sweden, Finland, Great Britain, Belgium and Switzerland.

The strategies adopted and the degree of progress with the programmes in view of opening a deep geological formation disposal facility varies from country to country.

The research and studies in progress mainly focus on 3 types of geological formation:

- granite,
- sedimentary formations and more specifically clay beds,
- salt.

The programmes developed in Sweden, Finland have clearly chosen granite bedrock. Granite is also studied in Canada, Korea, Japan, China and also Switzerland.

For a number of years, clay formations have also been the subject of important research and studies in Belgium (Boom clay) and Switzerland (Opaline clay). The same applies for Germany with salt formations.

NOTES

* In particular within the Radioactive Waste Management Committee (RWMC), or the Integration Group for the Safety Case of Radioactive Waste Repositories (IGSC).

** In particular through publications issued by the Waste Safety Standards Committee (WASSC).

*** In particular through Research and Development Framework Programmes in the nuclear field (EURATOM RDFP).



*Interim vitrified waste storage.
View in the lower part of the shafts (La Hague).*

Some countries, namely the United States, Germany and Finland, currently have underground facilities that receive radioactive waste.

In the United States: since 1999, the WIPP (Waste Isolation Pilot Plant) receives military waste containing transuranium elements in facilities dug in a salt formation.

In Germany: until 1978, low and medium-level radioactive waste was stored in the experimental centre established in a former mine exploited in a salt dome in

Asse in Basse-Saxe. In Morsleben, in former East Germany, a former salt mine was used as a radioactive waste disposal facility until 1998. Again in Germany, another site has just been licensed to receive a deep geological disposal facility: the Konrad site where all of the German non-heat releasing radioactive waste must be stored. This is a former iron mine exploited in a sedimentary formation.

In Finland: two waste disposal facilities have been dug in 70 to 100 m deep granite formations

to receive waste from the Olkiluoto and Loviisa power plants. These facilities located close to the two power plants have been in operation since 1992 and 1997.

Other countries such as Korea, Canada or Hungary plan to use underground facilities to store their long lived and short lived low and medium-level waste (LMLW-SL). Various disposal strategies exist for this last category of waste (disposal in geological formations for some and surface disposal for others) but they are motivated by considerations other than safety (political choice usually depending on the social and economical context). With regard to the safety of disposal facilities, it should be noted that all of the countries affected have shared their views by specifically approving the international standards published by the IAEA on the subject.

A deep geological formation disposal facility designed for receiving long lived high-level waste is yet to be commissioned. However, in addition to France, three other sites are the subject of current relatively advanced projects.

In the United States: a license application procedure for creating a disposal facility was filed in 2008 on the Yucca Mountain site. The formation concerned is a volcanic tuff formed 11 to 14 million years ago. Exploratory studies are conducted on the site from an underground facility dug out in 1993 to demonstrate the feasibility of a disposal facility. At present, the project has been suspended.

In Finland: the process started on the Olkiluoto site plans to file a license application to construct a spent fuel disposal facility in the granite in 2012. Commissioning is envisaged for 2018. The construction of an underground laboratory to deepen the characterisation of the site is in progress.

In Sweden: investigations were started in 2008 on 2 granite sites, Östhammar near Forsmark, and Oskarshamn. The Östhammar site near Forsmark was retained in 2009, the procedure subsequently plans to obtain a license to construct a disposal site in 2011 and its commissioning in 2020.

Except for France, in the majority of other countries, disposal facility design and site research programmes are less advanced.



Each package has its bar code stating the origin, the level and the nature of the radioactivity that it contains.

Several countries decided to create underground research laboratories to advance their disposal in geological formation projects. These laboratories generally have the following two objectives:

- either to develop knowledge and validate methods and technology with a relatively general scope on a given type of bedrock,
- or to characterise a specific site in the aim of evaluating the feasibility of a waste disposal facility.

Methodology laboratories meeting the first objective have been

created in granite in Canada (Whiteshell URL currently being dismantled), Sweden (Äspö laboratory), Switzerland (Grimsel laboratory) and more recently in Korea (Kaeri Underground Research Tunnel - KURT) and Japan (Tono Mizunami URL). The same type of laboratories exist in clay formations in Belgium (Mol), Switzerland (Mont-Terri), and Japan (Horonobe URL). The Tournemire experimental station operated by the IRSN belongs to this category. It should be noted that the Äspö underground research laboratory, operated since 1990 close to Oskarshamn in Sweden, has hosted techno-

logical tests for around the past 10 years in order to validate the Swedish and Finnish KBS3 concept.

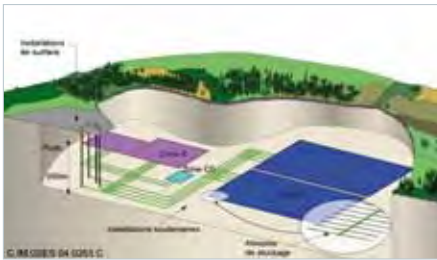
A site qualification and characterisation laboratory exists in the United States (Yucca Mountain in the tuff). Another is under construction in Finland (ONKALO on the Olkiluoto site). The Andra underground research laboratory in Bure belongs to this category of research facility.

4

Disposal in deep geological formations in France

The 2006 Act on nuclear waste management confirmed the option of reversible disposal in a deep geological clay formation for long lived high-level waste. The construction of this structure, designed to protect humans and the environment from the radiological hazards related to this waste over hundreds of thousands of years, has been entrusted to Andra.

The project currently under consideration is sited in the Meuse/Haute-Marne district. It involves a facility located 500 m deep in a clay formation the properties of which are similar to those currently studied in the Bure laboratory. This 15 km² facility will have approximately 500 cells for receiving various types of HL (fuels from research) and LL waste.

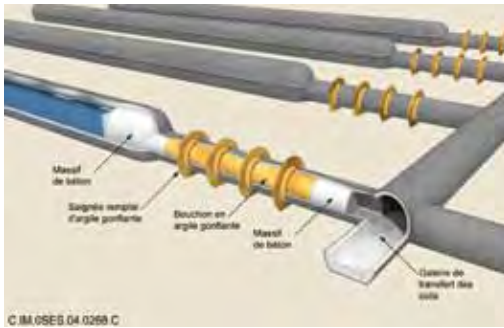


Cross-section of the deep disposal facility project.

□ Technical and scientific challenges for the IRSN

It is for IRSN to provide, within the deadlines laid down by law for the phasing of this project, a clear opinion on the ability of such a structure to achieve its mission under the best possible conditions. In 2005, analysis of the preliminary report by Andra led the IRSN to express an initial positive opinion on the feasibility of a disposal facility in the clay formation located 500 metres deep on the borders of the Meuse and Haute-Marne districts, close to the town of Bure.

Between now and 2015, the IRSN must decide on the various safety elements, that would result from detailed definition of the project. First of all, the safety of a major underground nuclear facility that will be in operation for almost a century. But above all, the ability of this structure, and of the clay formation surrounding it, to contain, long enough, the radio-nuclides through the various barriers before to reach surface ecosystems for the most mobile of them.



Storage cells.

Obviously, the IRSN cannot rely on the specific results from Andra's investigations and its scientific support in a field where no scientific certainty exists. All of the models for the long-term evolution of a highly complex system of interactions are effectively discussed, and surrounded by a number of uncertainties: radiolysis, chemical reactions, flow physics within the environments between the radioactive materials stored, the components of the packages and the structure (metals, concretes,

etc.), the argillite area damaged by the digging, and the healthy bedrock possibly altered in places, which relate to the long-term behaviour of the structure and its contents.

The forecast for the long-term radiological impact on humans and ecosystems comprises further uncertainties, and the application of simple equations governing the usual radiation protection goes without saying.

□ A specific scientific approach

The IRSN must therefore use a specific scientific approach to establish its critical analytical procedure on data and conjectures independent of that of the

designer of the structure, even if it naturally has access to raw data from the Bure laboratory. In view of its limited resources, the institute has chosen to focus

its research effort on two objectives:

- on one hand, the constitution of national (in particular CNRS, with the Trasse group) and European research groups to have a wide range of expertise,
- on the other hand, the development of an experimentation platform in clay formation, via the Tournemire tunnel (Aveyron), dug in bedrock resembling that of the Meuse district, which is 250 metres thick, but has very easy access since it is an old railway tunnel dating back to the end of the 19th century.

In addition, the IRSN is developing its own ability to model the overall behaviour of a disposal facility using the MELODIE software.

□ Important results

Very important results have already been obtained in Tournemire and new programmes are under way to support the Institute's programme to assess several key points for the radiological safety of the future disposal facility.

In particular, this concerns the effects of bedrock desaturation

The IRSN is participating in several research projects organised by the European Union within the context of the Technological Research and Development Framework Programme (RDFP).

Europe also has four research platforms in clay formations: Bure, Mol in Belgium, Mont-Terri in Switzerland and Tournemire. The IRSN (along with Andra) is also involved in several European programmes calling for these experimental sites, and in analytical experiments that aim to model the behaviour of the components of the disposal facility, and its ultimate environmental impact.

on the damage, the impacts of degradation products for the materials introduced into the disposal facility (concrete and metal compounds) on the clay's containment properties, or even assessment of the effectiveness of the embedding of underground structures.

□ A clear choice

Therefore, these research programmes conducted by the IRSN will provide France with an exceptional ability to assess the safety of long lived high-level radioactive waste geological disposal sites.

When making the decision to construct such a structure, in addition to Andra's know-how as a designer, and the National Assessment Commission's guarantee of scientific rigour with the preliminary research, this ability will be much appreciated for constituting a sufficient

national consensus. The IRSN's studies confirmed that the transfer times of water in healthy clay bedrock are extremely slow (a few centimetres per million years).

They also showed the complexity of predicting the behaviour of the bedrock around tunnels (damage, desaturation, etc.). Research conducted on faults with little vertical movement tested the limitations of the seismic reflection geophysical method for identifying them.



Tournemire Tunnel.

Photo credits: Andra (p.6, p.22, p.23/Films Roger Leenhardt p.16/Philippe Demeil p.7 left, p.20/Anne de Henning p.14) ■ CEA (P. Dumas cover) ■ Cogema (Philippe Lesage inside front cover/Eurodoc La Hague p.2/Jean-Claude Grelier p.9 droite/Eurodoc Centrimage p.18) ■ EDF Médiathèque (Henri Cazin p.5 left/Jean-Claude Raoul p.5 right) ■ IRSN (p.24/C. Cieutat p.4 left, p.8 top, p.9 left, p.17, Olivier Seignette/Mikaël Lafontan p.25) ■ SOCODEI (Patrick Lefèvre p.7 right) ■ RHODIA (p.4 right)

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The Institut de radioprotection et de sûreté nucléaire (French Institute of Radiation Protection and Nuclear Safety) is in charge of the scientific assessment of nuclear and radiological risks. A public body of industrial and commercial nature, the IRSN carries out research and assessment missions for the public authorities and general public. A reference organisation in France and worldwide, it brings together over 1,700 people covering various disciplines from life sciences to nuclear physics. It conducts research and assessments in the following fields of application:

- protection of the population and the environment against ionising radiation risks;
- safety of facilities and the transport of nuclear materials and their protection against malicious acts;
- inspection of nuclear materials and products that may be used for the manufacturing of weapons;
- crisis management.

It also helps provide information to the public.

Radioactive waste

The generation of electricity, but also hospitals, universities and specific non-nuclear industries produce radioactive waste.

All of the regulations specific to waste in general apply to radioactive waste. But radioactive waste emits radiation and is therefore a specific hazard for human health. It should therefore be managed with special care, from its production to its final destination. The creation of suitable waste disposal systems constitutes a major challenge for all players present, manufacturers, regulatory authorities, public authorities, local communities and the population.



IRSN certified quality
management system

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