

THE RADIOACTIVE WASTE MANAGEMENT PROGRAM IN FRANCE

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SUMMARY

For every category of waste, from very low level (VLL) to high level and long lived (HVL) waste, ANDRA, the French national agency for radioactive waste management, is responsible for proposing suitable disposal solutions.

For low and intermediate level, short lived waste, engineered solutions have been implemented for many years. Centre de la Manche, opened in 1969, is a near-surface disposal facility now entering into its institutional control period. With this experience of 25 years, ANDRA has designed, built and, since 1992, has been operating the Centre de l'Aube disposal facility, offering a volume capacity of 1 000 000 m³ (about twice that of Centre de la Manche). This capacity covers the French needs for more than 50 years.

For other categories of waste, ANDRA is performing investigations. In particular, for VLL, ANDRA has developed a disposal design which has been submitted to waste generators and safety authorities. A site could be selected during 1999.

High-level waste strategy is governed by the waste act, issued on December 30, 1991 which defined three research areas to be intensively investigated. These areas include :

- Partitioning and transmutation,
- Deep geological disposal through the construction of underground laboratories,
- Long term interim storage.

The second option comes under ANDRA's responsibility and the two others under the French Atomic Energy Commission.

At the present time, three sites have been investigated, public inquiries have been held and favourable votes of local community's representatives have been registered. The applications for constructing and operating underground laboratories on these three sites were submitted to Government at the end of 1996. On 9 December 1998, the French Government decided the construction of two laboratories, in accordance with the law of 30 December 1991 : the first one on the East site at Bure and the second one on a new granitic site that ANDRA has to find.

An overall assessment report related to the results obtained for the three research areas will be presented to Government in 2006.

INTRODUCTION

On December 30, 1991, the law which represents the basic framework for radioactive waste management was enacted in France. It entrusted ANDRA, the French national agency for radioactive waste management, with the responsibility for proposing suitable disposal systems for every category of waste.

Radioactive waste management systems must be commensurate with the risks involved, which is gauged by two parameters : the activity level and the half-life. Table 1 presents the status of the waste classification and the related choices for their management.

Table 1 : Status of disposal systems according to the radioactive waste classification

ACTIVITY LEVEL	HALF - LIFE	
	Short (T < 30 y)	Long (T > 30 y)
Very low	Under study	
Low	Surface disposal	Under consideration
Intermediate	Surface disposal	Law issued on 12/30/91
High	Law issued on 12/30/91	Law issued on 12/30/91

VERY LOW-LEVEL WASTE

The specific activity of the very low-level waste (VLL) is less than 100 Bq/g, with an average of 10 Bq/g and returns to the natural radioactivity level in a few decades. Although this activity may appear very low compared with the other waste categories, the guideline is to set up management systems developed on an individual case basis and adapted to the characteristics of each waste category and in particular of VLL waste. In France, no activity limit has been fixed below which the waste issued from nuclear facilities could be considered as a non-radioactive one.

VLL radioactive waste comes from two origins :

- nuclear industry, following the dismantling of nuclear power plants, research centers and fuel cycle plants,
- conventional industries such as chemical, involving metallurgy using ores containing traces of natural radioactivity.

More than 90 % of VLL consists of inert materials, rubble, scrap iron, with some thermal insulation and technological waste, with virtually no chemical toxicity.

The average radiological spectrum includes the following radionuclides (^{54}Mn , ^{58}Co , ^{60}Co , ^{63}Ni , ^{90}Sr , ^{234}U , ^{238}U). Other radionuclides such as ^3H , ^{65}Zn and ^{134}Cs may be present in traces.

The reasons underlying the creation of a specific disposal facility are, in one hand, a precautionary principle which requests that VLL waste management be conducted with rigor, in a regulatory framework and with substantial monitoring, and in the other hand, the principle of economic optimization.

The disposal concept is based on two independent barriers. The first one is composed of a top geomembrane, which prevents water from infiltrating into the waste and a bottom geomembrane. The waste is therefore kept dry. Leak tests are performed by a drainage layer placed at the base of the waste and a test sump.

The first barrier must procure a perfect seal for several decades. The second barrier consists of natural clay. Tightness under the facility is provided by a layer at least 5 m thick and by a capping system employing the same material. The overall system ensuring the containment module must guarantee long-term retention.

These two first components making up the containment module are supplemented by the rest of the geological environment, consisting of the clay layer outside the module and the aquifer.

The disposal facility would be monitored at three levels : in the trenches, inside the facility perimeter (rainwater, air, gamma exposure, aquifer), outside the facility.

The waste is placed in batches in layers about 1 m deep and stabilised by sand to fill the voids and to prepare the base for the next layer. A trench drainage system collects any water in a sump surmounted by a manhole accessible from the capping.

A geomembrane welded to the previous one guarantees upper tightness. It is surmounted by a drainage system which removes the water, a clay layer and a backfilling material consisting of clay and topsoil.

Excavation and trench preparation operations are conducted at the production rate. All disposal operations are performed under a roof covering all the pairs of trenches in operation.

The surveillance phase is estimated at thirty years after operations are terminated. These measures are aimed to check the absence of dissemination of radioactive materials and to confirm compliance with the regulations governing this type of waste.

Figure 1 shows French VLLW disposal concept.

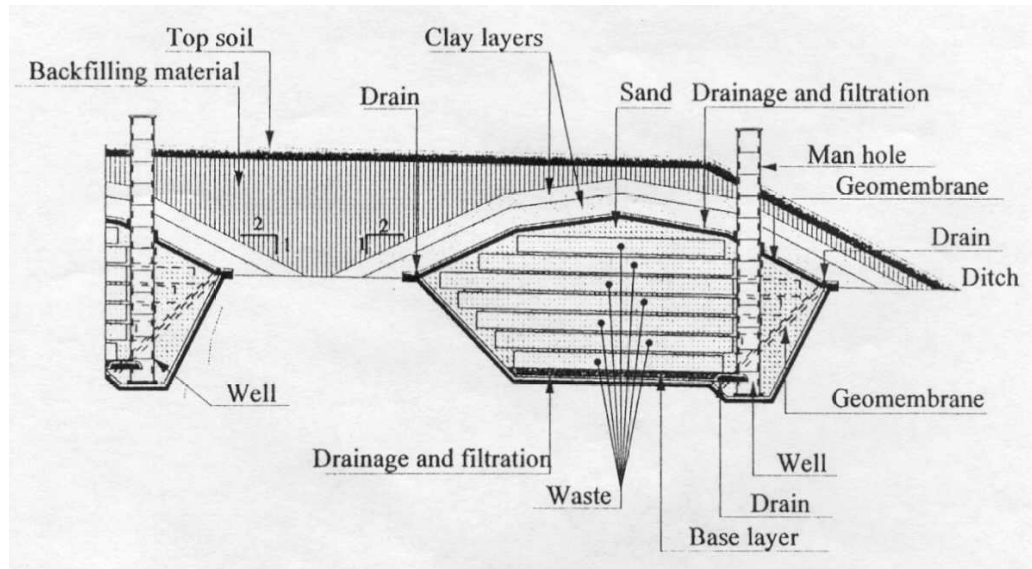


Fig. 1 : VLLW disposal concept

LOW AND INTERMEDIATE LEVEL, SHORT LIVED WASTE

Unlike VLL waste, low- and intermediate-level short-lived waste requires industrial operations before disposal. The first facility (Centre de la Manche) was commissioned in June 1969 in the commune of Digulleville. After accommodating more than 500 000 m³ of radioactive waste, it was closed in July 1994. Since then, the final cap has been installed. It consists of a multiple layer complex which comprises, starting from the base of the cap :

- a bottom layer of schistose material designated to create the basic slope of the disposal cap and contribute to the imperviousness of the cover
- a drainage layer made of fine-grain sand to collect water beneath the bituminous geotextile,
- a bituminous geomembrane made of a bitumen saturated geotextile,
- another drainage layer made of fine-grain,
- a semi-impermeable layer of schist to minimize the amount of water infiltration and to protect the membrane against root systems and burrowing animals,
- a layer of topsoil to promote grass growth.

Water recovered from the cap is collected in networks surrounding the site. Runoff water is separated from infiltration water by, on one hand, a system of large pipes for surface water located underneath the site perimeter road and a system of smaller pipes for infiltration water drained from the cap.

The administrative formalities for closure and transition to the institutional control period are under way. The procedure involves the examination of the technical files and safety assessment report prepared by ANDRA.

The Centre de la Manche disposal facility was relayed in 1992 by the Centre de l'Aube, which was subjected to intensive geological investigations before the site was selected. It is built on an Aptian sand, which itself overlies an impervious clay layer. Hence, it is distinguished by a relatively simple hydrogeological system, with a well-known outlet.

The disposal concept of the Centre de l'Aube is based on a multiple-barrier system, including the

package, the disposal structures and the geological environment. The packages play the role of blocking the radioactive materials and preventing their dispersion. All the waste is mixed with an immobilization material (concrete, grout, resin, bitumen) in concrete or steel containers. Figure 2 shows Centre de l'Aube facility.



Fig. 2 : The Centre de l'Aube disposal facility

As in the Centre de la Manche, a piezometric network is used to monitor the aquifers on and around the site. The results of the analyses performed on samplings are published regularly and communicated to the local administration and population.

Its capacity of one million m³ is designed to accommodate low-level, short lived waste generated until around 2040. In the interest of optimizing the long-term disposal, both technologically and economically, ANDRA and the waste generators have jointly developed an integrated waste management system that covers all phases of waste processing, transportation and disposal, pursuant to regulations. The cornerstone is a comprehensive quality assurance program, yet it remains flexible enough to accommodate special cases.

ANDRA issued technical specifications that require waste generators to submit a waste acceptance file on each type of package they plan to produce for ANDRA's approval.

The second major component of the integrated waste management system involves tracking the waste from the moment it is generated through its final disposal. ANDRA sets up a computer network link between waste generators, disposal facility and its own headquarters in this purpose.

HIGH-LEVEL AND LONG-LIVED WASTE

High-level and long-lived radioactive waste comes mainly from nuclear power plants. For countries, as France, which reprocess the spent fuel to recover the uranium and the plutonium from the irradiated fuel, the main waste stream appears at this step. It consists, firstly, with the fission products and minor actinides stabilized in a glass matrix by the French vitrification process. It is, secondly, constituted with the structures remaining after dissolution of the fuel : hulls and end

pieces, mainly of zircaloy, which are compacted and, finally, different technological waste which are compacted, cemented or bitumized. Activity is chiefly due to small quantities of fission products, long-lived actinides and activation products. High level and long-lived waste could also be partly some unprocessed fuels.

Spent fuels and vitrified waste are classified as C waste. Hulls, technological waste and bitumized sludge are classified as B waste.

C waste have high specific activity, which results in a very high thermal load, at least for several hundred years, until the high activity mainly due to ^{90}Sr and ^{137}Cs , with half-lives close to thirty years, have decayed. B and C waste contain relatively large amounts of very long-lived radionuclides (^{239}Pu , ^{237}Np , etc).

The first investigations to dispose B and C waste in a deep geological repository were started in France in the early 1980s. A research program on sites in four different geological formations (granite, clay, salt, shale) came up against opposition from the local population. After a moratorium declared in 1990 by the Prime Minister, and following the surveys conducted independently for the Government and the Parliamentary Office for Scientific and Technological Decisions, a bill was presented to the French Parliament. The law passed on 30 December 1991 sets the research framework.

On the one hand, it opens up the programs to the assessment of the different management systems, demanding research in three areas :

- separation and transmutation of the long-lived radionuclides present in the waste,
- reversible or irreversible disposal of the waste in a deep geological formation, particularly through the construction of underground laboratories,
- conditioning and long-term storage of the waste.

The law of 30 December 1991 presents several other characteristics of a new approach of rad-waste management. It provides for fifteen years of research without any industrial decision on geological disposal. In this framework, the underground laboratories, built to study the in situ rock properties, cannot be transformed into a disposal, even if these properties are very favorable, by technical factors alone. The Parliament has to debate and pass a new law in 2006, after examining the results of the three research alternatives to decide on further action on research and, subsequently, the creation of a disposal facility.

To obtain precise and also comprehensible scientific information, the law of 30 December 1991 set up a National Evaluation Commission (NEC) composed of eminent scientists :

- six qualified personalities, including at least two international experts, designated equally by the National Assembly and the Senate, on the proposal of the Parliamentary Office for Evaluating Scientific and Technological Alternatives,
- two qualified personalities designated by the Government on the proposal of the Supreme Council for Nuclear Safety and Information,
- four scientific experts designated by the Government on the proposal of the French Academy of Sciences.

This Commission will be charged with preparing an annual report on the state of progress of research in the three directions, and on the progress achieved abroad in the area. It will be required to prepare the final summary report of 2006 on which the Parliament will have to debate.

Studies under way on separation and transmutation, and also on waste conditioning and long-term interim storage, are coordinated by the French Atomic Energy Commission (CEA). Studies conducted on waste disposal in geological repositories are coordinated by ANDRA.

In the spirit of the law, a new approach is decided by the Government for siting an underground research laboratories has to be conducted. Among all the French locations favorable to a geological repository, the choice is made on the basis of representations by the territorial authorities (municipal, departmental and regional councils) which votes to host such a laboratory.

To seek such a local consensus, in late 1992, the Government charges a member of the National Assembly, Christian Bataille, already the reporter to the Assembly on the law of 30 December 1991, with a *mediation* mission. The *mediator* is asked to examine the situation in some thirty Départements, including eight which volunteered to receive him. Four of them, the Haute Marne, Meuse, Vienne and Gard, finally declare their candidacy with the virtual unanimous support of their local elements.

In January 1994, the Government authorizes ANDRA to initiate preliminary surveys accordingly. Rapidly, Haute Marne and Meuse sites merge under the same one, at their frontier, known as East site.

Seeking the involvement of the local players, the law promotes also openness and transparency. The annual reports of the NEC are made public. Besides, on each prospecting and subsequently underground laboratory site, a Local Information Committee (LIC) is formed, provided with operating and investigative resources. It includes State representatives, elected territorial officials, members of environmental protection associations, members of farm unions, representatives of professional associations, personnel connected with the site, and ANDRA. According to the law, the LIC is informed about the nature and progress of the work, as well as the results. It can be consulted on any matter pertaining to the operations of the underground laboratory which have any effect on the environment and the neighborhood. It can have hearings conducted as well as second analyses by approved laboratories.

And finally, according to the law, a financial help to the economic development of the departments favorable to the construction of an underground laboratory is set in place : 5 MFF/year during preliminary surveys and 60 MFF/year during the building and the operating the laboratory. After two years of surveys by surface techniques, essentially geophysical prospecting and drilling, no prohibitive factor is identified on any of the three sites, and ANDRA is authorized to compile and to file the applications for permits to install and operate an underground laboratory on each of them.

On East site, the relevant formation lies at a depth between 400 and 600 m and corresponds to Callovo-Oxfordian stage. It consists of an argillite composed of about 40 to 45% clay (interbedded illite/smectite), about 30% carbonates and 25% quartz. It is 150 million years of age and about 130 m thick.

On Vienne site, the favorable host rock identified belong to a Hercynian granitic environment. It consists of a granodiorite deposited about 350 million years ago, at 450 m depth and over a thickness of several hundred meters.

On Gard site, a favorable Cretaceous formation lies at a depth between 400 and 800 m and dips northward. It dates from the Vraconian (100 million years). This silty formation corresponds to a shallow coastal sedimentation zone where marine sediments accumulated (40% clay and 10 to 20% carbonates) together with continental debris (30 to 50% quartz), regularly mixed by animals and wave action.

The three permit applications are examined in 1997. The examinations covered :

- technical analysis by the Nuclear Installation Safety Directorate, the French safety authority ; it issues a favorable opinion to go on operations on the three sites,
- public inquiry ; the Inquiry Commissions submitted conclusions favorable to continued operations on each of the three sites,
- the vote of the local and territorial authorities, which very largely support the going on of the operations on the three sites.

The National Evaluation Commission has expressed a favorable opinion of the two clay sites but underlines some specific technical difficulties about the granite of the Vienne site, related to its confinement properties.

On 2 February 1998, the Government announces that the decision to create underground laboratories will be taken in a few months, after a supplementary report on reversibility of a repository, requested from the National Evaluation Commission. This report, transmitted to the Government in June 1998, confirms the reversibility of a repository during its operation, which becomes less and less easy with time after this phase and particularly after its closure. Consequently, it concludes that a deep geological repository fits better the immediate disposal of low and medium activity long-lived waste (B waste) than high activity ones (C vitrified waste or spent fuel). Actually, B waste are final waste, without any heat generation when C waste, and especially spent fuel, are matters which could be reprocessed in the future to recover valuable elements or, in another hand, to reduce their toxicity, depending on the scientific progresses.

Simultaneously on February 1998, a greater effort on R&D is asked to the CEA, dealing with long term storage. Particularly, a report on the concept, the interest and the feasibility of a subsurface storage center is requested from the CEA before the end of 1998. This report is transmitted to the Government at the end of November 1998.

During site characterization and in connection with rock properties, ANDRA improved disposal concepts. These concepts, after several iterations, have to be integrated to the final report of 2006 as disposal design, on which the decisions for the future strategy on the high level have to be decided and voted.

The master plan for research programs is shown in Figure 3. The main deadlines are the following:

- 1999, with the beginning of shafts drilling for the underground laboratories,
- 2001, with access to the underground laboratories and the beginning of downhole ex-

periments, which have been prepared for many years in methodological laboratories abroad,

- 2005, with submittal of the summary file for evaluation.

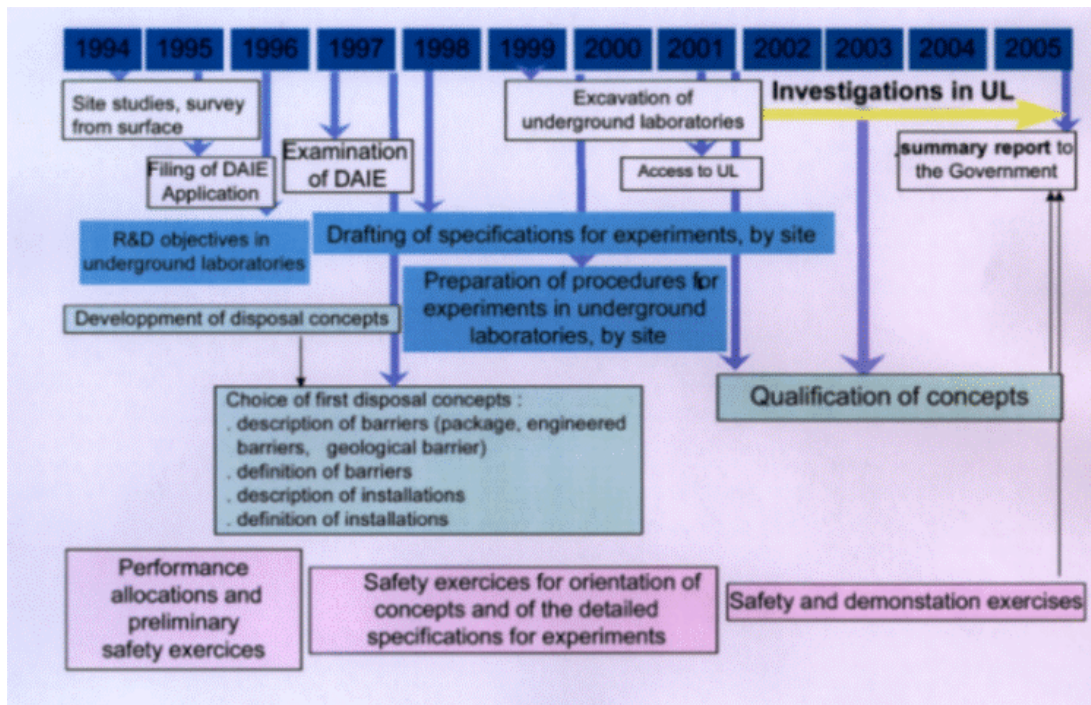


Fig. 3 : The timetable for research programs

CONCLUSION

The different types of waste produced either by the nuclear industry or by the various organizations using radioactive materials are taken into account in the management system that has been set up in France. This begins with the National Radioactive Waste Inventory, which serves to identify and locate the waste produced in the past and to list current production.

Depending on the characteristics of the waste, different appropriate systems are then proposed. These are in a preliminary stage for very low-level waste. They have reached industrial maturity for low- and intermediate-level and short-lived waste. The Manche and Aube facilities provide long-term safety guarantees for man and his environment. High-level, long-lived waste is subject to intensive research program, carried out within the specific framework set by the law of 30 December 1991, which stipulates a Parliamentary debate in 2006 to decide on the best alternative.

On 9 December 1998, the Government decided the construction of two laboratories, in accordance with the law of 30 December 1991 : the first one on the East site at Bure and the second one on a new granitic site that ANDRA has to find. The corresponding Decree of the Council of State should be published within next few months.