40 YEAR EXPERIENCE OF RADIOACTIVE WASTE DISPOSAL IN FRANCE

Nicolas SOLENTE, Gerald OUZOUNIAN, Michel DUTZER, Roberto MIGUEZ
ANDRA Agence Nationale pour la Gestion des Déchets Radioactifs

1-7 rue Jean Monnet 92298 Châtenay-Malabry

ABSTRACT

France's experience in the management of radioactive waste is supported by forty years of operational activities in the field of surface disposal. This feedback is related to three disposal facilities:

- Centre de la Manche disposal, not far away Cherbourg, from design to post-closure facility.
- Centre at Soulaines-Dhuys from site selection to design to operation during nearly 20 years.
- Centre at Morvilliers from site selection to operation for seven years now

During the operational period of Centre de la Manche disposal facility (1969-1994), the safety concept for low-and intermediate level short lived waste (LIL-SLW) was developed and progressively incorporated in the procedures of the facility. The facility entered its institutional control period and the experience of this facility has been useful for the operating facilities.

Centre de l'Aube that took over Centre de la Manche, and Morvilliers for very low level wastes. Both facilities currently accommodate the major part of the volume of radioactive wastes that are generated in France. However disposal facilities have to be considered as rare resources. Then new waste management options are being investigated as the disposal of large components or recycling metallic wastes within the nuclear industry.

1. INTRODUCTION

France's experience in the management of radioactive waste is supported by forty years of operational activities in the field of surface disposal of low-and intermediate level short lived waste (LILSLW) and of very low level waste (VLLW). So-called *Centre de la Manche* started operation in 1969 and about 527,000 cubic-meters of waste packages were disposed till the end of operation in 1994. After capping works, this facility has now entered its institutional control period. So-called *Centre de l'Aube* took over *Centre de la Manche*. Start up occurred in 1992 and its design took benefit from *Centre de la Manche* experience. More recently, in 2003, a new disposal facility, *Morvilliers disposal facility*, was created for very low level wastes, in particular to accommodate wastes generated by decommissioning activities.

Andra is now responsible for three disposal facilities that are at very different stages of their life-phases: institutional control, mature operational phase, beginning of operational phase. The feedback of the experience of one facility to the other ones is an important issue in order to ensure safe and exemplary operation. It is also important for the development of new disposal routes. Furthermore there can be changes in the operational conditions of the facilities: new needs for disposal may appear, improved considerations for sustainable development, new regulations.

Therefore Andra has to continuously adapt its industrial tools to this changing environment. This includes of course the tools to take the wastes in charge, but it also includes the capacity to re-assess the situation of the closed facilities.

2. CENTRE DE LA MANCHE: 25 YEARS OF IMPROVEMENTS OF OPERATION AND 15 YEARS OF INSTITUTIONAL CONTROL

Located in the north-western part of the Cotentin Peninsula, between Cherbourg and Cap de La Hague, Centre de la Manche was commissioned in 1969 and received low and intermediate-level short–lived waste packages until June 1994.

2.1 25 years of operation

Centre de la Manche currently covers an area of about 15 hectares. Its operation was authorised by an Order signed by the Prime Minister on 19 June 1969 and was first given by the French Atomic Energy Commission (*Commissariat à l'énergie atomique --CEA*) to a private company called INFRATOME, under the technical and financial control of a Liaison CEA-INFRATOME Committee. Disposal started in October 1969 (1).

Pursuant to the new nuclear legislation implemented in 1973, a first safety report was prepared in 1975. The CEA took back the operational responsibility of the facility in 1978 and entrusted it in 1979 to the new French National Radioactive Waste Management Agency (Andra) created within the CEA by a Cabinet Order. December 1991 waste act changed Andra into an independent body.

Waste acceptance criteria have considerably evolved during the operational lifetime of the *Centre de la Manche.* The Order of 19 June 1969, creating the facility, referred to concentrations using the volume as a reference (maximum permitted concentration in drinking water or MPC) to define the disposal modes, water being the main contamination vector. Beyond 1,000 MPC (5.10^{-5} Ci/m^3 for ^{239}Pu) waste contained in drums and products in bulk had to be disposed of in concrete cells before being grouted with liquid concrete. The waste could also be disposed of directly in the ground provided it was packaged, in cement blocks or in cemented drums, against any risk of water leaching. Below 1,000 MPC, bulk waste could be disposed in trenches. So when operations started at the facility, there was no activity limit for the waste, except to define the packaging and disposal modes.

Figure 1 : concrete trenches for grouted waste (1969)

Therefore the first types of disposal cells were simple trenches, concrete tranches or above ground platforms. Due to water infiltration problems, three simple trenches were built but only two were used and waste from one was retrieved.

First activity limitations for waste were proposed in the 1975 safety report and the conceptual design with regards to safety for a surface disposal facility was progressively established. Finally, basic safety rule RFS I.2 formalized in 1985 the incorporation of these acceptance

Figure 2F : above ground platform (1971)

Figure 3 : disposal operations in monolithic cells (1985)

Figure 4 : above ground disposal structure (1988)

Figure 5: general view of Centre de la Manche (1991)

criteria into the long-term safety objectives. It prescribed that, in the post-institutional control phase after no more than 300 years, the intrinsic safety of the disposal facility relied on the activity limitation in long-lived emitters of the disposed waste and on site properties. Thus, the average specific activity in alpha emitters of the entire set of waste packages contained in the disposal facility at the end of the institutional control period should not exceed 0.01 Ci alpha per tonne (370 MBq alpha per tonne). The maximum specific activity in alpha emitters of each waste package had to remain under 0.1 Ci per tonne (3.7 GBq alpha per tonne).

As a complement, basic safety rule RFS III.2e (October 1986) imposed systematic waste packaging and established minimal characteristics, particularly with regard to containment, with which packages must comply depending on the nature and activity of the waste. Containment properties of waste packages and disposal structures had to be considered till the end of the institutional control period.

ANDRA reflected all these requirements in its technical specifications and notified the waste generators who intended to send their waste to the Agency. Moreover, an acceptance process was set up to verify, first, that waste packages satisfied ANDRA's technical requirements and also that waste generators had well identified and implemented the prescriptions ensuring the quality of the packages generated.

The design of the disposal structures continuously improved. In particular rainwater that may have been contaminated by waste packages was separated from rainwater that fell outside disposal structures: a dedicated water collection system have been gradually implemented since 1979. This system includes an underground gallery.

The traceability of waste packages took benefits from the availability of computerized systems. In 1984 a fully computerized system was implemented to perform a follow up of waste packages, from generating facilities to disposal structures.

Handling techniques remained rather rustic during the whole operational time of *Centre de la Manche*. Generally workers were operating in the very vicinity of waste packages. At the end of operation in 1994, about 527,000 m^3 of waste packages have been disposed.

2.2 Entering the institutional control period

The project submitted by Andra to protect the disposal facility against rainwater was to implement a multilayer capping system with a bituminous membrane. The choice of bitumen instead of a mineral material was motivated by the possibility of subsidence of packages in the most ancient parts of the facility. Capping works began in 1991.

Figure 6: cross section of the capping system

The way Andra planned to enter the institutional control period was proposed to a public inquiry in October 1995; it gave a positive result. However the French government decided in February 1996 to create a commission to assess the situation of *Centre de la Manche*. This commission issued a report in July 1996 (2). The report considered that the capping system was an important tool for the long term safety of the disposal facility but recommended improvements with regards to the durability of the bituminous membrane and the stability of the slopes. It also emphasized the need to maintain memory of the facility as long as possible. The report of the commission is still considered as a reference document for surface disposal facilities.

Figure 7 : Centre de la Manche capping system

A new approach for the institutional control period was proposed by Andra and after a second public inquiry in February 2000, the order authorizing to launch the institutional control period was issued on the 10th of January 2003.

2.3 Present situation and forecast evolution

Even if tritium can still be detected in groundwater and in the rivers, the impact of *Centre de la Manche* appears to be low (3). The theoretical dose to a hypothetical critical group living close to the river and using its water is about 0.6 µSv/year (2007).

	1991	2007
Volume	21,000 m3	300 m3
Alpha activity	0.4 GBq	0.005 Gbq
Beta activity (except 3H)	1.3 GBq	0.01 GBq
Tritium	1,700 GBq	4.4 GBq

TABLE I Water collected in the underground gallery

Table 1 shows the efficiency of the capping system for the reduction of the reduction of volume and activity collected in the underground monitoring galleries. Most of the volume of collected water comes from local defects that are not related to the quality of the membrane.

Figure 8: Settlements observed in the bituminous membrane.

Figure 9 : copy of documentation on "permanent paper"

However in some places subsidence of the capping system has been observed and it was necessary to reinforce locally the stability of the slopes (3). Therefore, according to the order of January 2003, Andra submitted proposals to the regulatory body in order to improve progressively the situation. They were instructed and Andra decided, in 2009, to repair the different cover layers. A 4x8 m of bituminous membrane, in which there was no rip, was replaced, after new material was added to rebuild the previous slope.

During the years of institutional control period, the maintenance of the memory of the facility was organized. The documentation of the facility was duplicated on a long duration paper. A copy of this documentation is presently stored at the French National Archives. A summary was also prepared for local administration and municipalities (1). These data will be useful to review periodically the situation of the disposal facility in the future.

3. *CENTRE DE L'AUBE* DISPOSAL FACILITY

3.1 17 years of operation

Centre de l'Aube disposal facility design fully takes into account French basic safety rules that were developed during the operational time of *Centre de la Manche*. The facility makes use of an up-to-date technology that improves radiation protection for workers.

Figure 10 : centre de l'Aube disposal facility

The site was selected because of a very simple geology, which fitted with safety requirements: a layer of sand above a layer of impermeable clay protecting water resources. The outlet of underground water in the layer of sand is well identified: a small river which flows along the facility.

The nuclear site has a surface of 60 ha with a disposal zone of 30 ha for a capacity of 1,000,000 m3 of waste packages. It is located in the Aube

District near Soulaines-Dhuys village. The facility started up in 1992.

Figure 11 : disposal vaults at Centre de l'Aube

The disposal structures are designed in order to protect waste packages from rainwater: temporary cover by movable buildings fitted with waste package handling equipment, vault closure completed by a coating of impermeable material, finally a capping system for the institutional control period. A Separative Water Collection System collects any water that may have seeped into the disposal system. Vaults are constructed above groundwater level.

Waste packages with concrete envelopes are disposed of in vaults that are backfilled with gravel, waste packages with metallic envelopes are disposed of in vaults that are grouted with concrete, or «grouted vaults».

According to the experience of *Centre de la Manche*, Andra is performing a very cautious acceptance of wastes that contained significant quantities of tritium. It is clear that for these wastes, the multibarrier containment system implemented in *Centre de l'Aube* is questionable as tritium can diffuse easily through the concrete of the packages or of the vaults. The 28th of June 2006 waste act prescribed that a specific storage route should be developed for them.

The local information commission of the facility, which includes local representatives and members of associations, is keeping a very close eye on that topic. In 2007 the commission performed independent measurements in the environment of the facility and inside the facility (4). No contamination was detected.

However better understanding and characterization of tritium migration through the disposal barriers remain important issues for Andra, in particular to improve acceptance criteria.

Andra and waste generators are improving continuously the knowledge of long lived radioactive content of the wastes that are disposed. Some of the radionuclides are difficult to measure and scaling factors methodology is implemented. This content determines long term safety and some wastes (for instance wastes that contain chloride 36) have to be diverted to a more appropriate disposal route under development (long lived low level disposal facility for instance).

At the end of 2010, 240,000 m^3 of waste packages have been disposed. Some delivered wastes are compacted or grouted inside the facility prior to disposal. Since the start up of *Centre de l'Aube* every actor is aware that a disposal facility should be considered as a rare resource et should be spared as much as possible. Deliveries of low and intermediate short lived wastes have been indeed divided by a factor of about 3 since 1989 (from 35,000 to 12,000 m^3 par year). *Centre de l'Aube* closure is then forecast by 2040-2050 and the facility should be able to accommodate new waste streams provided by decommissioning activities.

3.2 From operational wastes to decommissioning wastes

Considering shutdowns of ageing facilities, decommissioning waste management was yet becoming an emerging issue, in particular for research laboratories or fuel cycle facilities. Furthermore, according to the strategy of immediate decommissioning that is promoted in

France, EDF took the decision in 2001 to undertake the total deconstruction over a period of 25 years of all its reactors that have ceased commercial operation. The effects of this change cannot yet be seen on deliveries; however it is expected that these programs will increase significantly deliveries to *Centre de l'Aube*. Figures from the National Inventory issued by ANDRA in 2006 show that the annual delivered volume could be increased by a factor 2 between 2010 and 2020.

Figure 12 : grouting of metallic packages in a disposal vault

A modification of the spectrum of waste packages is also expected as a consequence of decommissioning operations. *Centre de l'Aube* could accommodate more metallic drums to be compacted and more 5 or 10 m^3 metallic boxes. Therefore tight coordination between Andra and waste generators is required in order to adjust the disposal tools to new waste streams if necessary.

Figure 13 : disposal of a reactor vessel head

First years of operation showed that the standard types of waste packages that are accepted could meet most of waste generators needs. However it appeared that occasionally large component disposal could be an interesting disposal mode. The option of removing some dismantled material as a single piece instead of cutting it can reduce dose exposure for workers involved in decommissioning operations. Andra proposed to accommodate some large components in standard vaults or in dedicated vaults; 52 reactor vessel heads are presently received in vaults with specific handling equipment.

But the relevance of this disposal mode should be assessed not only with regards to decommissioning works but also to transportation and disposal. It might not be relevant to dispose of such items if the disposal capacity consumption would be quite higher than with standard packages. A general doctrine, involving decommissioning operators, transporters, disposal operators and regulators, has to be established to assess the relevance of large components disposal. International experiences will be useful to promote this approach.

4. VERY LOW LEVEL WASTES: A NEW DISPOSAL ROUTE *CENTRE DE MORVILLIERS* FACILITY

The implementation in France of a disposal facility dedicated to very low level waste is a consequence of French regulation related to waste management in nuclear facilities. Pursuant to the Order of 31 December 1999 (4), every French nuclear facility must establish a *waste zoning* with a view to separate any sector where waste is actually or likely to be contaminated or activated (nuclear waste zone) from all other sectors where there is no waste contamination or activation risk (conventional waste zone). The need for a safe and cost effective disposal facility became more stringent with the development of the decommissioning program.

One basic principle of the repository design was to comply with regulations governing disposal facilities for non-radioactive hazardous waste. By applying such a principle, it is possible to accommodate both radiotoxic waste and toxic chemicals. Containment therefore relies on the properties of a low-permeability surface clay layer in which the repository is implemented.

Figure 14 : general view of Morvilliers disposal facility

Within the clay layer, trenches are excavated. Sides and bottom are protected by a watertight membrane. The waste is piled over the membrane, while a mobile roof protects operations throughout loading. Trenches are backfilled and sealed with the same membrane. The repository is ultimately covered with clay. An inspection hole is used to check that there is no water seepage around the waste.

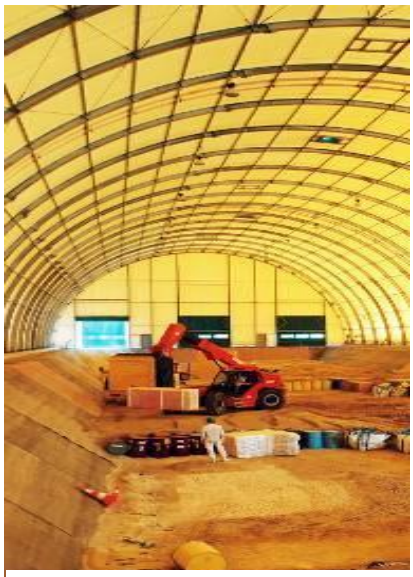

Figure 15 : waste packages disposal at Morvilliers facility

After operations, a post-closure monitoring phase of approximately 30 years is scheduled.

Andra selected a suitable site in the village of Morvilliers, Aube Prefecture, close to the *Centre de l'Aube* disposal facility, thus allowing for synergies between both facilities. An area of 45 ha was surveyed where a clay layer varying between 15 and 25 m in thickness was identified. The capacity of the facility is 650,000 m^3.

Waste annual disposed volume is presently 26,000 m^3. Due to a demand by waste generators, arrangements were taken to increase the disposal flux to 32,000 m^3 (longer disposal cells).

The facility can also accommodate large components. However for very heavy components (as steam generators), Andra is investigating the opportunity to develop dedicated disposal cells with appropriate handling tools.

The principle of waste zoning implies that a large part of the waste has a very low activity and, as a matter of fact, there is sometimes only a presumption of contamination. Therefore the relevance of the disposal of significant quantities of metallic wastes can be questionable, as these pieces may not be contaminated or easily decontaminated. Recycling of metals within the nuclear industry, for instance in disposal structures, would be a more relevant option, in particular with regards to sustainable development. This approach has been initiated by waste generators and is fully supported by Andra. This would also be a way to save disposal capacity.

Figure 16 : large component disposal at Morvilliers facility

5. CONCLUSIONS

For 40 years the disposal of the major part of the volume of radioactive waste that is generated in France has become a common practice. The conceptual design of surface disposal facilities with regard to safety has been progressively constructed in Centre de la Manche since 1969. One important milestone was the issue of basic safety rules I.2e and III.2e in 1984 and 1986. These safety rules are still the foundations for the design of the present facilities. Centre de la Manche disposal system has continuously improved. The improvement was not only related to the design of the disposal vaults but also to the acceptance process with the development of waste packages specifications. Centre de l'Aube disposal facility superseded Centre de la Manche in 1992 and took benefit of Centre de la Manche experience. The handling tools and conditioning equipments were updated according to the available techniques et the construction time. Due to the new regulation on waste zoning in 1999 and to face waste generation by decommissioning programs, a new disposal route was implemented for very low radioactive waste.

The closure of Centre de la Manche and the process to enter the institutional control period have demonstrated that handling waste in vaults is only a part of operational activities. An exemplary management of Centre de la Manche is also a condition to maintain confidence of all stakeholders. This management does not only include environmental monitoring and facility maintenance but also the constitution of documentation in order to enable periodical safety reviews of past practices with the present perception. Andra considers Centre de la Manche disposal facility as an important safe heritage that will provide fruitful information for the development of disposal routes for the future. Therefore Andra operational activities include the maintenance of this heritage and of its knowledge.

At the end of 2008, about 850,000 m3 of waste packages have delivered to disposal facilities. Efforts done by waste producers have enabled a significant decrease of low and intermediate level short lived waste deliveries; volumes have been divided by a factor of about 3 since 1988. The management of decommissioning waste should be facilitated by this situation. However densification should also be searched for very low level waste in order to improve the efficiency of the use of the disposal space. The development of new disposal services for large components, of recycling routes within the nuclear industry will contribute to preserve disposal capacities. An optimized use of disposal capacities is indeed also a way to maintain confidence of the populations living in the neighborhood of the facilities.

REFERENCES

P. CHARTON "Centre de Stockage de la Manche – Mémoire de synthèse pour les générations futures", downloadable at www.andra.fr (2008).

Ministère de l'Environnement, Ministère de l'Industrie, de la Poste et des Télécommunications "Rapport de la Commission d'Evaluation de la Situation du Centre de Stockage de la Manche", (1996).

ANDRA : "Centre de Stockage de la Manche – Rapport annuel de surveillance 2007 dans le cadre de l'article 21 de la loi TSN", downloadable at www.andra.fr (2008).

*ACRO : "*Analyse des niveaux de la radioactivité dans les environs du centre de stockage FMA-VC de l'Aube", downloadable at www.acro.eu.org (2008).

ANDRA : "Inventaire National des Déchets Radioactifs et des Matières Valorisables", downloadable at www.andra.fr (2006).

"Arrêté du 31 décembre 1999 fixant la réglementation technique générale destinée à prévenir et limiter les risques et nuisances externes résultant de l'exploitation des Installations Nucléaires de Base", *Journal Officiel de la République Française* (15 Février 2000).