# A Challenge for Radioactive Waste Management: Memory Preservation - 8014

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## ABSTRACT

Andra, the French National Radioactive Waste Management Agency, is responsible for managing all radioactive waste in France over the long term. In the case of short-lived waste for which disposal facilities have a life expectancy of a few centuries, the Agency has set up a system for preserving the memory of those sites. Based on the historical analysis on a comparable timescale and on an appraisal of information-conservation means, a series of regulatory as well as technical provisions was made in order to ensure that sound information be transmitted to future generations. Requirements associated to the provisions deal mostly with legibility and a clear understanding of the information that must be decrypted and understood at least during the lifetime of the facilities (i.e., a few centuries). It must therefore be preserved throughout the same period.
Responses to the requirements will be presented notably on various information-recording media, together with the information-diffusion strategy to the different authorities and structures within French society. A concrete illustration of the achievements made so far is the *Centre de la Manche* Disposal Facility, which was closed down in 1994 and is currently in its post-closure monitoring phase since 2003.
In the case of deep geological repositories for long-lived radioactive waste, preserving memory takes a different aspect. First of all, timescales are much longer and are counted in hundreds of thousands of years. It is therefore much more difficult to consider how to maintain the richness of the information over such time periods than it is for short-lived waste. Both the nature and the form of the information to be transmitted must be revised. It would be risky indeed to base memory preservation over the long term on similar mechanisms beyond 1,000 years. Based on the heritage of a much more ancient history, we must seek to find appropriate means in order to develop surface markers and even more to ensure their conservation over compatible timescales with those of deep geological repositories. It will also be necessary, in the light of the experiments and efforts made in order to decrypt the messages written on rupestral paintings or in pyramids, find suitable expression means that will help, not the next few generations, but much more future generations, to grasp the meaning of what we aim at transmitting them.
This paper presents the state of the French reflection on memory preservation and transmission over the very long term, for timescales consistent with the long-lived radioactive geological waste disposal projects.

## INTRODUCTION

The very long timescales to be considered for disposal of radioactive waste (from centuries to much more longer times depending on the type of waste disposed) implies that memory be kept at least during the lifetime of the radionuclides contained in the waste. One of the stakes is to be able to define such a lifetime, either through the specific activity or through other types of indicators. Radiotoxicity is also often used, but in all cases a threshold must be defined to determine the endpoint of the considered lifetime. Dealing with centuries in the case of short-lived radioactive waste, or with hundreds of thousand years in that of the long-lived radioactive waste implies keeping a certain level of memory along time. Requirements have been published in France to prescribe a series of measures to be taken in that sense [1] [2].

Since the duty of memory constitutes a statutory requirement for Andra, the National Radioactive Waste Management Agency in France, four major objectives are to be answered:

- to inform future generations about the existence and the content of the site, especially with regard to the risk of human intrusions, in case the facility was forgotten;
- to facilitate the understanding of the observed phenomena;
- as a consequence, to ensure that any relevant corrective actions can be carried out under safe conditions, if necessary;
- and finally, since they get the information and the knowledge about an existing radioactive waste disposal, to allow for future generations to make any decision concerning the future of the site, especially in response to technical and societal developments.

As part of the requirements, Andra has also the obligation to duplicate that memory in two copies containing legible and readily understandable information on a suitable support for preservation over several centuries and to deposit those copies in a secure location.

As illustration, two extracts of these requirements are reported here:

- Technical requirements of the Nuclear Safety Authority for the "Centre de la Manche" Disposal Facility (excerpt relating to memory tracking). The "Centre de la Manche" Disposal Facility received packages between 1969 and 1994. It has now entered into its post-closure monitoring phase:
  - Section VI. deals with specific requirements relating to the long-term archiving of information:
    - *A long-term archiving system designed to preserve documents and data throughout the entire monitoring phase of the facility shall be implemented with a view to informing future generations on the existence and content of the site and to facilitating the application of any future corrective actions, if need be. The information support shall be suitable for preservation purposes over several centuries. Documents shall be archived under safe and suitable conditions in two copies kept in two separate locations. The operator shall ensure that all archived documents are legible and understandable.*
- Basic Safety Rule III.2.f regarding the study of a repository for high-level and long-lived radioactive waste in a deep geological formation (excerpt relating to memory tracking):
  - Section 5.3. defines the situations concerned
    *An "initial" period of 500 years corresponding to the memory preservation of the repository ensures that any human intrusion within the repository zone remains extremely unlikely. It also corresponds to a significant decay of the activity of short-lived or intermediate-lived radionuclides.*
  - Human intrusions are described in Annex § 3.1.
    *A minimum date shall be set before which no involuntary human intrusion shall be possible due to the ongoing memory tracking of the existence of the repository. That memory relies on the perennity of any measures designed for archiving purposes or relating to corporate documents, surface markings, etc. Under such conditions, the memory of the existence of the repository may be reasonably estimated to last for a minimum of 500 years. That 500-year value shall be adopted as the first theoretical date for the occurrence of any human intrusion. The definition of the characteristics of human intrusions is based on the following conservative hypotheses:*
    - *the existence and location of the repository have been forgotten;*
    - *the future technology level remains the same as today's.*

Thus as far as the existence of the repository is kept recorded in the human memory, one can take care of it and protect from any human intrusion. Basic assumption is that the level of technology remains at least the same as the one existing at the time of the repository was created, and that all measures can be taken to keep integrity of the design and the planned life of the facility.
The first application for authorising the transition of the "Centre de la Manche" into its post-closure monitoring phase was submitted to a public inquiry in 1995. It resulted into a favourable opinion, paired with recommendations. However, in response to the concerns of the populations and of their representative associations, the government created an independent commission in February 1996 with a view to assessing the situation of the facility. The Commission, headed by Mr M. Turpin, confirmed the consistency of Andra's inventory, the absence of any significant risk around the facility, Andra's compliance with the Law of 30 December 1991 and the role of the cover to ensure long-term safety [3]. The Commission also issued recommendations, especially with regard to the memory tracking of the facility by:

- confirming the use of paper for long-term archiving purposes;
- requiring the preparation of largely-distributed synthetic memory, reporting the main information to inform about the existence of the repository, with its main characteristics;
- requiring the implementation of easements, which are part of the memory preservation since legal disposal are taken in order to avoid any other use of the land than the initially authorized one for the repository;
- requiring that communication actions be maintained with the public and the local monitoring committee throughout the post-closure monitoring phase.

Additionally to the requirements, the recommendations of this Commission serve as the base for Andra's reflections concerning the memory of its disposal facilities.

## RISK AND SAFETY ASSESSMENT TO DEFINE AND STRUCTURE MEMORY

Andra structured its duty of memory around six major actions:

- Designing scenarios of potential risks in phase with the safety approach;
- Selecting relevant and sufficient information in response to those scenarios;
- Grading the selected information;
- Ensuring the legibility and understanding of the selected information;
- Using supports design to last over several centuries;
- Ensuring that those supports are accessible to any person who may need them.

In the case of the "Centre de la Manche", for example, 13 scenarios of potential incidents were developed in line with the safety report of the facility. Scenarios are divided into three levels and each scenario was accompanied by a set of questions and answers designed to allow future generations to make decisions with a full knowledge of the facts.
Based on the geometry of the facility involved, Andra selects the different information required in order to respond to the pre-set scenarios (documents, plans, photographs, computer data, etc.).
The information was graded according to two major guidelines: the constitution of a so-called "detailed" memory as required by the operator of the facility (or by anyone who will be responsible for managing or transforming that facility in the far future) and the provision to local and national decision-makers of a so-called "synthesis" memory that includes the most significant data (background notes and description, summaries of inventories and of regulatory files, etc.).
Andra verifies that every selected document remains legible. In order to help future generations fully understand the content of the archives, a glossary and a list of acronyms with their meaning are also

provided. The Agency also explains the structure of its archiving system and has used a proven and stable terminology to prepare a brief summary of each file.
All required information to understand the synthesis and detailed memories are duplicated or printed on "permanent paper" (see next sections). The latter is only handled with gloves in order to minimise pollution risks.
The detailed memory is kept in two copies: the first copy remains at Andra and the second copy is sent to the French National Archives (Centre of Contemporary Archives, Fontainebleau). The synthesis memory is made available not only to notaries, mayors, subprefects, general councils, prefects and consular chambers of the relevant departments, but also to all national and international authorities concerned.

## FROM "ALL DIGITAL" TO "ALL PAPER"

While digital media is attractive for the present generation, it quickly becomes technologically obsolete. Archival quality paper in a secure environment is preferred alternative mainly for conservation reasons. As in the case of an increasing number of companies, Andra has fully digitised the management of its routine information. Specific databases, for example, are dedicated to the management of different inventories (national, per facility, provisional, etc.), environmental measurements (air, water, milk, grass, sediments, etc.), measurement results in the underground laboratory (automated collection of values recorded by sensors in the rock, etc.). The Agency also has an "electronic" management system designed to recognise the existence and content of its thousands of documents.
Digital control ensures "instantaneous" access to all information from any location. It also provides "maximum" security through daily backups conducted from different locations, a high compactness and an interesting archiving solution over the relatively short term.
Unfortunately, new information technologies evolve very rapidly and become obsolete within 10 to 20 years: what would we be able to do today, for example, with the first diskette format (8"), which has been obsolete for about 20 years? That upgradability raises a major problem for memory preservation over the long term, since it is not sure whether future generations will always have the proper means to follow the developments of information systems. That is especially true with regard to the migration of information from one solution to the next, since it might prove very expensive in time and money. In response to such a risk, Andra applied the precaution principle and printed on "permanent paper" all required information to be kept for the memory tracking of waste repositories.
"Permanent paper" , which details are discussed in the following sub-section complies with an international standard (ISO 97.06). Provided that it is used with care and kept in suitable premises, it is designed to last for several centuries. It therefore appears as a sound solution against technical evolutions.

### Permanent paper

Until the middle of the 19th century, paper was made out of rag. At the beginning of the industrial revolution, its composition was modified by the massive use of wood pulp and rosin during the sizing stage. Those components produced an acid that generated the self-destruction of paper within a few decades.
Consequently, the need to manufacture a special paper for long-preservation purposes became obvious. During the 1950s, papermakers in Great Britain, followed by their counterparts in the United States, started to produce such a paper, although no specific rules existed in the field. The very first standard defining the nature of "permanent paper" was issued in the United States in 1975 (ANSI Z39-48), before the publication of two international standards in 1994 (ISO 9706: Permanence Requirements) and 1996 (ISO 11108: Durability Requirements), respectively. The permanence requirement is the ability of the paper to remain chemically and physically stable over time. The durability requirement is its ability to withstand normal wear, especially due to manipulations. Those standards integrate more than a century's experience feedback from the major international archive systems.
The main features of "permanent paper" include:

- no mechanical wood pulp,

- no recycled paper,
- no composite material,
- no wood pulp mix in the manufacturing process,
- minimum alkali reserve of 2% in calcium carbonate generating a relatively basic pH (from 7.5 to 8.5); common white paper is rather acidic due to the bleaching process involved,
- Kappa number under 5; the Kappa number expresses the resistance of the paper to oxidation. The lower the Kappa number, the clearer the paper remains naturally. Common paper made with wood pulp normally has a Kappa number varying between 25 and 50, before bleaching,
- tearing strength above 350 mN for common grammage (80 grams per square meter).

## DETAILED MEMORY OF ANDRA'S FACILITIES

### Detailed memory of the "Centre de la Manche".

When the "Centre de la Manche" (figure 1) entered into its monitoring phase in 2003, its detailed memory contained 10,732 documents, consisting of 442,938 pages spread over 60 linear metres. The overall data available on the facility were sorted out and the decision was made by Andra to keep 33% of the documents and 5% of the correspondence. It should be noted that no more than about 100 documents are necessary for the routine monitoring of the facility. Key dates for the realisation are:

- 1984: beginning of reflections on memory tracking;
- 1990: beginning of support inventory;
- 1995: beginning of document selection;
- 1998: launching of duplication programme on permanent paper;
- 2003: preparation of summaries and glossary;
- 2004: transfer to French National Archives.

**Fig.1. Photo of Centre de La Manche disposal facility for LILW**

### Detailed memory of the "Centre de l'Aube".

Experience feedback regarding the implementation of the detailed memory of the "Centre de la Manche" highlighted the need to track down memory every time a document is produced.
Hence, in the case of the "Centre de l'Aube" (figure 2), every document that Andra produces or receives from its suppliers is inputted into its information system (content management software) and "ticked" accordingly it is meant to be part of the detailed memory. Those documents are reproduced in two copies on permanent paper on a regular basis. The first instalment of documents, which covers the first 10 years of operation of the "Centre de l'Aube", was deposited at the French National Archives in 2005.

**Fig.2. Centre de l'Aube disposal facility for LILW**

**Detailed memory of the future facilities.**

Andra will apply the measures of the "Centre de l'Aube" for any other future disposal facilities, including its project of deep geological repository.

## LONG – TERM MEMORY IS NOT ONLY ARCHIVES

The memory of any disposal facility does not rely exclusively on the archives of its life phases. It also includes two complementary aspects: easements and exchanges with the representatives of the populations concerned.
The purpose of easements is to limit or prohibit the use of the lands after the shutdown of the facility in order, for example, to prevent any drilling or building operations. According to the current regulations, those easements may be replaced by a modification of the zoning map, provided that the same objective is sought. In both cases, the goal is to maintain the memory of the site on the cadastre and to preserve its integrity or to ensure that any future activity or development is conducted on the site with a full knowledge of the facts.
The memory of a disposal facility must also be rooted in the collective memory of the local population and in its representative institutions. In order to maintain that objective as long as possible, it is necessary for Andra, the current manager of the facility, and for all potential managers in the future, to pursue communication actions (e.g., site newsletter) and for a local information or monitoring committee,

consisting of representatives from the populations and the administrations concerned, to continue to hold hearings with the manager of the facility. Both measures are already in place in all Andra facilities.
Hence, through a largely distributed synthesis memory, a collective memory constantly revived around the site and institutions serving as guarantors of the compliance with easements or the zoning map, the risk that the disposal facility might fall into oblivion is extremely reduced at least for the next few generations.

**BEYON THE MILLENIUM SCALE**

Is it possible to believe that the existence of a disposal facility might fall into oblivion at some point in the future? When a facility is shut down (transition into the post-closure monitoring phase), several redundant memory-tracking systems are in place in order to remember the existence of that facility:

- local/regional memory (communication actions and local information committee);
- local/regional institutional memory (easements, zoning map);
- long-term archiving (detailed memory and synthesis memory).

Those memory-tracking mechanisms are redundant initially, but will gradually disappear at various timescales. Actually, it is very likely, in light of the experience feedback from the transmission of the heritage of past centuries, that:

- the local/regional memory will be lost within a few generations (i.e., 1 to 2 centuries);
- the local/regional institutional memory should last longer (2 to 5 centuries), provided that no excessive societal rupture occurs in the meantime due, for example, to the aftermath of a war or to a revolution-type phenomenon in the country;
- long-term archiving should provide an additional timescale (i.e., 5 to 10 centuries) especially with regard to the level of the synthesis memory being largely disseminated and slightly sensitive to potential societal ruptures.

Beyond 1,000 years, nevertheless, it would be more hazardous to assume that such mechanisms would remain valid. When considering our past heritage at a multimillennial scale, it is obvious that we still have some very rare parchments and many works of art (rupestral paintings, megaliths, pyramids, amphitheatres etc.). Based on the perennity of those remains from the very far past, why not build what could be called “surface markers” over our own disposal facilities? Even if they withstood erosion or deliberate destruction, it would still be necessary to understand their meaning. Examining the past shows that human beings dedicate a considerable amount of energy to understanding what they discover if it relates to civilisations or religions, that is, to the origins of mankind, its beliefs and, more generally, to the mysteries of life, even if they fail to trace back its true meaning (i.e., Easter Island statues). However, it is far from sure that future generations would be as willing to show the same interest concerning an industrial theme of the 20th and 21st centuries, among the thousands of other topics reflecting our current civilisation. When looking at the Carnac megaliths, for example, do we stop to think for one moment that they might indicate the presence of buried artefacts several hundreds of metres underneath? In any case, Andra participates in international reflections on the subject.

## POSSIBILITY TO FALL INTO OBLIVION FOR A DISPOSAL FACILITY

As mentioned before, it is very unlikely that the memory of a disposal facility would be lost during the first centuries of its monitoring phase, in light of the redundant means set in place to counter that loss. Those few centuries are sufficient for the radioactivity of low-level and intermediate-level waste to reach a lower value than ambient natural radioactivity. Under such conditions, even if the disposal facility were to fall into oblivion after a few centuries, it would not constitute any risk for people who would use it as a working site, build their homes nearby or live in the neighbourhood.
The situation is not the same for long-lived waste, since radiotoxicity lasts over much longer timescales. In the case of some radioelements, the installation of surface markers would not be sufficient, because the memory-tracking programme must extend over hundreds of thousands of years. Loosing track of such a type of disposal facility is therefore a normal phenomenon in the lifetime of the facility. However, although they would have forgotten the existence of a disposal facility for radioactive waste, future populations would still be protected against the radiotoxicity of the waste, because:

- the “safe” in which the radioactive waste is located is designed to prevent any radionuclide migration towards outlets that are likely to lead to the surface (e.g. groundwaters) over such a timescale;
- the depth of the disposal facility would prevent any risk of natural erosion and, coupled with the selection of the site within a zone with no known natural resources deep underground (absence of ore, petroleum, gas, etc.), would drastically limit the risk of any potential human intrusion (drilling, mining, etc.).

REFERENCES

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[3] Rapport de la Commision Turpin, février 1996