

# **“Long-term Records, Memory and Knowledge Preservation – Recent thinking and progress in the field of geological disposal of radioactive waste, and further avenues of research”**

*by*

*Claudio Pescatore<sup>1</sup>*

## **Foreword**

Nuclear waste management concerns issues further into the future than anything humanity has ever envisioned. Disposal of high-level waste and spent nuclear fuel involves challenging technical and scientific problems, but also social and ethical issues. One of them concerns the preservation of Records, Memory and Knowledge (RK&M). RK&M is gaining increasing international attention. It is more specifically given special attention in connection with the application for building a final repository for spent nuclear fuel submitted by the Swedish Nuclear Fuel and Waste Management Co in 2011. This application is presently being assessed by relevant authorities in Sweden including the Swedish National Council for Nuclear Waste. In 2015 the Council sponsored a project proposed by Claudio Pescatore – former Secretary at the IAEA/NEA with a PhD in nuclear engineering – on Knowledge Preservation and Time Capsule. The Council wishes to express our sincere gratitude to Dr. Pescatore for the completion of this project and we are pleased and honored to publish this report on the outcome of this project.

Stockholm, October 25th 2016

For the Swedish National Council for Nuclear Waste

Carl Reinhold Bråkenhielm  
Chairperson

---

<sup>1</sup> Claudio Pescatore is currently Research Affiliate with the University of Calmar, Sweden.

## **About this document**

This document was prepared within the context of the project "Knowledge Preservation and Time Capsules" of the Swedish National Council for Nuclear Waste (the Council, hereafter). It was presented to Council members and other relevant Swedish actors in June 2016. The present version incorporates feedback received thereafter.

The document serves as an introduction to recent thinking and progress in the field of preservation of Records, Knowledge and Memory for geological disposal of radioactive waste and proposes avenues for raising awareness of this topic and investigating it further.

The text is organized in 6 Chapters as follows:

- Chapter 1 reviews the current international positions in the field of RK&M preservation in connection with radioactive waste disposal
- Chapter 2 explains that present preservation intentions may well go unfulfilled in a long-term perspective, and identifies issues and questions deserving the attention of the institutional players
- Chapter 3 describes a way to tool up for apprehending the future, which provides a basis for developing strategies of RK&M preservation
- Chapter 4 identifies time capsules as a promising means for helping preserve RK&M. Their linking to local lore would keep the attention alive and stimulus on future institutional players towards respecting previous oversight commitments and carrying out further RK&M preservation activities.
- Chapter 5 provides conclusions. Namely that the time to prepare the future is now and that now is the time to federate all relevant audiences, generate mutual learning and advance the field. Current issues worth addressing are presented in the Annex. The Annex contains a list of issues and questions especially targeted to the Swedish context, which can be easily generalized internationally.

A reference bibliography and figures are included in separate sections.

### **1. Now is the time to prepare the future**

Preservation of Records, Knowledge and Memory (RK&M) is needed to support the lengthy and complex decision-making processes taking place across the operational lifetime of a radioactive waste repository. These processes may well exceed a hundred years. They concern licensing, monitoring, ensuring retrievability, supporting land-use restrictions and reduce loss of information during potential transfer of responsibilities for oversight both in the period of operation and after closure of the repository.

Given that the post-closure period of interest in geological disposal of spent fuel and high-level waste extends to hundreds of thousands of years, doubts have been aired whether oversight over the closed repository should continue. Questions have been raised on other accounts on whether society should keep memory of the location, contents, decision-making of geologically disposed-of spent fuel and high-level waste. There is, however, today important support to the idea that oversight should not be relinquished and that – to the extent practicable – all future generations should be given the possibility to make their own informed decisions about dealing further with the waste, including taking care of an – albeit very unlikely – unwanted evolution of the repository.

The international support in favor of uninterrupted oversight and of RK&M preservation provisions is outlined in three important documents issued between 1997 and 2014. Namely:

- The *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* [IAEA, 1997] expressly engages the over 100 signatory governments to put in place provisions that ensure continued safety after-closure. Any institutional oversight would require preservation of RK&M.
- More recently, the *International Commission on Radiological Protection* issued their recommendations in the field of geological disposal [ICRP, 2013]. These recommendations indicate that (a) a closed repository should be seen as a functioning nuclear facility and (b) although the repository should be designed and built to be safe without the intervention of Man, there ought to be no intention to relinquish oversight after closure. Surveillance of the closed facility should continue for as long as practicable. Memory provisions are mentioned as part of oversight, and the involvement of society is expressly invoked. A succinct presentation of the ICRP observations and recommendations is available [NEA, 2014a].
- The *Radioactive Waste Management Committee* of the OECD Nuclear Energy Agency (NEA) has outlined guiding principles in the field of RK&M preservation for geological disposal of waste [NEA, 2014b]. They are in line with the ICRP recommendations (see above). Amongst other things, the RWMC collective statement observes that the long operational phase of the repository provides an opportunity for reflection and for developing workable RK&M preservation strategies. The time to prepare the future is now!

While international institutions (see above) have formally expressed themselves in the field of RK&M preservation, one of them – the OECD\NEA – is also carrying out an international project in this area<sup>2</sup>.

There has been, as yet, no strong *questioning* by local stakeholders of the ability to preserve RK&M across generations, although the issue has surfaced. [NEA, 2013] Interest as well as demands from local stakeholders audiences are expected to grow, as witnessed (a) by the large contingent of local organizations participating in the event "Constructing Memory – An International Conference and Debate on the Preservation of Records, Knowledge and Memory of Radioactive Waste across Generations"<sup>3</sup>, which was held in Verdun, September 2014. Other interested parties, such as academia, were also well represented at Verdun; and (b) by the discussions at the recent FSC workshop on "*Bridging Gaps - Developing Sustainable Intergenerational Decision-Making in Radioactive Waste Management*" held in Bern 7-9 September 2016, where preserving information for future generations was one of the important themes<sup>4</sup>. Besides, local stakeholders have been asking for continued monitoring of the facility after closure [NEA, 2013], which implies continued oversight and preserving the necessary RK&M.

It was observed by some that, with the Verdun conference, a new multidisciplinary field of study was born and that it seems useful, at this stage, to federate all the audiences, generate mutual learning and advance the field.

## **2. Present intentions may go unfulfilled in a long-term perspective, which calls for institutional attention and future planning.**

---

<sup>2</sup> <https://www.oecd-nea.org/rwm/rkm/>

<sup>3</sup> The attendees, from 17 countries, came from technical organisations (35%), local stakeholder organisations (24%), academia (7%), research institutions (5%) and archives (5%). The remaining 14% included visual artists and staff of international organisations (IAEA, EC), amongst others. The conference proceedings have been published [NEA, 2015].

<sup>4</sup> Press release <https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-63642.html> ; proceedings will be issued by the OECD/NEA likely in 2017.

Preserving records and maintaining knowledge and memory beyond a few generations is a task fraught with important challenges, starting already with the timescale of decades to hundreds of years. Suffice it to recall that, in 2011, the tsunami stones – erected along the coast of Japan during the past decades and centuries as warnings against the danger of living too close to certain parts of the coast – did not deter people from building housing in tsunami-prone areas, thus exposing the same people and/or their descendants to the catastrophe that hit the East coast of Japan that same year and caused the Fukushima disaster. [NEA, 2014d] Besides, large-scale projects that are likely to affect the life of future generations – like dams, harbors, roads, waste repositories, etc. – are routinely managed as if they were the concern of only of the present and succeeding generation. For instance, one rarely one asks the question if future safety authorities will exist or not and, if they exist, whether they have continued knowledge of past decisions and actions. The implicit assumption is that, in the future, appropriate institutions and individuals will have the memory as well as the knowledge, the records and the means to act further, and that the information will be as clear to them as it was to those who left it originally or who re-worked it in the intervening time. In the same vein, recent research at Linnaeus University shows that “the future”, as a concept by itself, is *not* systematically linked to contemporary heritage practices. [Linnaeus, 2014] This vision of a rolling present is not necessarily realized in practice: archives may disappear or be insufficient, records enabling the memory of why certain decisions were taken may be lost, funds may not be available when needed to perform corrective actions, nor may the relevant information be accessible or understandable. Present intentions may well go unfulfilled in a long-term perspective! This is why current *intentions should be identified, studied, and solutions devised for their fulfilling, which, in turn, is likely to require adaptation by present day institutions.*

In order to formulate intentions, basic questions to institutions include:

- Does an institutional view exist on informing the upcoming and later generations? Which are the target audiences? What are the periods of time?
- If the present, default strategy is to pass all official documentation on to the national archive: what, then, should be kept and what could be discarded? Would it not be useful to make a selection of documents, taking as well the different readerships into account<sup>5</sup>? Who would make this selection? Who would keep updating the info?
- What if a rolling present is not realized<sup>6</sup>? Which RK&M preservation strategies could cope with that? On which time scales?
- Would it not be wise to connect records keeping with knowledge and memory preservation so that society at large may also exercise some form of oversight?

An overarching question is as follows:

- *Do governmental institutions buy-in into the recommendations of the ICRP and others according to whom there should be no willingness to relinquish oversight of a repository?*

If not, why not? If yes, what do they plan to do about it? For instance, are they looking into the issue of transfer of responsibilities at a future time? Changes in responsibilities and in project directions can occur at any time and, typically, there is loss of information upon major decisions and changes to a project [NEA 2014e].

---

<sup>5</sup> The Verdun conference (see proceedings, p. 19) supported a rationalization of the documentation in at least three tiers. Progress in defining the topmost tier, the so called Key Information File (KIF), is reported in [Van Luik, 2106]. The bottom layer is the ensemble of all documents produced in the waste disposal program with limited structuring. The intermediate tier, described as the “set of essential records”, remains to be defined.

<sup>6</sup> In fact, what are the chances that a rolling present continues to be realized from decades to centuries?

### 3. Tooling up for the future

It is often said that the future is uncertain. Yet, for what concerns RK&M, it is certain that institutional systems will change – sometimes dramatically – that disruptions to our current societal systems will take place, that memory will not be maintained of everything deemed important today, that funds will be apportioned differently as value and financial situations change, that memory is more likely lost than kept. *Progress needs to be made in order to move from the rolling present approach to one that is more realistic concerning the future.*

#### *An important “new” concept targets societal attention levels in the future*

An important, new reference concept for dealing with time scales that may extend over generations is that of “oversight”, as developed by the [ICRP, 2013] in formulating their recommendations for radiological protection in the field of geological disposal<sup>7</sup>. Oversight is always by people, whereas “control” may be carried out both by people and inanimate objects<sup>8</sup>. Oversight includes regulatory supervision (such as control and inspection), institutional surveillance (e.g., environmental monitoring), preservation of societal records (such as archiving) and societal memory-keeping of the presence of the facility (e.g., through local lore). After closure, direct oversight by people - which has the effect of directing, ruling, regulating, restraining or limiting the management of the waste – will cease to exist, and only some surveillance can be carried out and, one day, surveillance may cease. This situation defines the three oversight regimes of direct oversight, indirect oversight, and no oversight, respectively. These oversight regimes are used to define radiological protection criteria [ICRP, 2013] and can be used as yardsticks for time scales of interest (see Figure 1) and for formulating the relevant intentions.

#### *Oversight regimes, time scales and relevant intentions*

The Verdun conference provided indicative time scales for the various oversight regimes. Namely, decades of direct oversight and centuries of indirect oversight, while no oversight may start in about one thousand years, say<sup>9</sup>.

Relevant intentions across the oversight regimes could be as follows:

1. To perpetuate a situation of direct and indirect oversight
2. To create the conditions to help return to a situation of oversight, if oversight were lost.

#### *Oversight implies RK&M. Constructing tables of RK&M tools.*

Oversight needs RK&M tools, such as national archives, libraries, local history societies, and museums. The efficacy of RK&M tools for favoring oversight will vary with time scales as well with the type of use to be expected from them. National archives, for instance, are longer lasting tools for preserving records than, say, a local library. At the same time, a local library will not store the same type of documentation (records) that an archive will. It could

---

<sup>7</sup> The concept was first introduced by the NEA Reversibility and Retrievability project. [NEA, 2011]

<sup>8</sup> The safety of a repository comes from oversight by man and from the “built-in controls” within the technical system that can provide for safety without the intervention of man. The latter will act in parallel to and independently of oversight by people, and act as the predominant safety providing future once the repository is closed. Oversight during the closure period will provide for freedom of action for dealing further with the waste and will provide additional confidence in safety.

<sup>9</sup> It is in the first thousands years that radiotoxicity is highest.

be said tentatively that, for preserving records, archives may last until the no oversight period; local libraries may only last during the short term; and that local library will offer complementary records (such as books, reviews) to archives and vice-versa over the short term. With these aspects in mind one could in principles construct tables of RK&M tools, indicating their target periods of efficacy, how they would support one another, etc. Claudio Pescatore made a proposal to the RKM project September 2015 on how to construct such tables (see Figures 2, 3). Continued work is needed to arrive at comprehensive tables. If research is pursued, tables such as these could help identify robust RK&M strategies.

Robust RK&M strategy

Three working principles seem important in order to arrive at a robust RK&M preservation strategy, i.e., a strategy that fulfills the intention to provide future generations with the RK&M about the disposed-of waste in the face of the uncertain future developments in society. Namely

- There is no single tool that can be totally relied upon to fulfill, alone, the long-term preservation task over the periods of interest
- A robust strategy must rely on different tools chosen to complement, re-enforce, and/or point to one another
- A robust strategy must rely both on mediated transmission (future seen as a rolling present) and on non-mediated transmission (future seen as a succession of up and downs in oversight efficiency<sup>10</sup>)

**4. Time capsules: an emerging means to support RK&M preservation**

Figure 3 describes a few classes of tools that may survive into the long term<sup>11</sup>. Time capsules are one of them. It turns out that they can be conceived as not needing the presence of Man to survive while they could still fulfill complementary role to archives as well as act as markers, and providing a transmission mechanism based on culture and tradition. [Pescatore, 2016] (see also hereafter) Time capsules are an emerging concept, in that they are not mentioned in the literature on repository marking.

Millennial time capsules near surface (MTCS)

One class of time capsules is especially interesting. Namely, science-based, millennial time capsules near surface (MTCS).

Amongst the examples of MTCS reported in Table 1, the Osaka Dual time capsule is described further (next section) as it provides good inspiration for radioactive waste disposal.

**Table. 1 Millennial time capsules in different categories**

	Also acting as a visible marker (Y, N)	Meant for opening after X years, or at an indefinite time (I)
--	--	---

<sup>10</sup> As the author Bill Bryson’s put it: “we (Men) are in the uncanny position of being life’s best friend and life’s worst nightmare”. Both extremes should be prepared for.

<sup>11</sup> The list may not be complete, and further research is needed to that effect.

Crypt of Civilization	N	6,000
Osaka Castle Time Capsule	Y	5,000
Memory of Mankind <sup>12</sup>	N	I
Westinghouse Time Capsules	N	5,000
Clock of the Long Now Foundation	N	I
Helium Centennial Time Columns Monument	Y	25; 50; 100; 1,000

### The Osaka Dual Time Capsule

The **Osaka Castle Dual Time Capsule** was built by the Matsushita (now Panasonic) Corporation. It consists of two time capsules, each having a 500-liters volume and buried together in the grounds of the Osaka Castle in 1970 at depths of 10 and 15 meters, respectively. (Figure 4) Each time capsule (intended for 5,000 years) is made of nickel-chrome alloy made into the shape of a kettle and is embedded within an external over-pack made of concrete. Bentonite packing is also used.

The two capsules duplicate one another and conserve objects, documents and materials whose choice resulted from suggestions from the Natural and Social Sciences as well as from the Arts. *Over 100,000 people in Japan provided suggestions to the Osaka time-capsules project.* One of the time capsules – the one buried closer to the surface – serves as a “pilot” and is supposed to be inspected according to a secular schedule. In the year 2000, the pilot capsule was unearthed and 173 items out of the 2,098 items were inspected (Figure 5). After the inspection, the capsule was buried again in November of the same year.

MTCS such as the Osaka Dual Time Capsule were/are conceived through a process that requires important resources, new scientific thinking, and involves society. The Osaka Castle Dual Time Capsule is the most elaborate and documented<sup>13</sup> scientific endeavor in the field of time capsules to date, and it deserves being studied for further inspiration in the field of radioactive waste management, for it has many qualities that may allow it to surmount successfully the challenge of time:

- It is a cultural object placed in a culturally protected ground
- It has been designed to withstand natural phenomena
- It is unobtrusive; the only sign is a plaque above ground.
- Its weight provides protection from easy removal
- It is under national jurisdiction. Literally it is in the portfolio of the Ministry of Education and of the Japanese nuclear regulatory commission (due to a Pu-powered clock to keep time in the capsules) and of the city of Osaka
- There exist 2 external replicas that are shown publicly and that help propagate memory
- One of the two capsules serves as a Pilot for inspection on a centennial schedule.
  - The opening of the pilot capsule at regular intervals provides the basis for a recurring ceremony (ritual) as well as the opportunity to apply most recent preservation techniques for improving on possible degradations.

<sup>12</sup> This is not a near surface concept, but it still belongs to the class of millennial time capsules.

<sup>13</sup> See <http://panasonic.net/history/timecapsule/>

### Specificities of MTCS

From the point of view of preserving repository information interesting characteristics of MTCS are that:

- They are easily understood means of preserving information
- Contain plenty of written records (and objects); digital records are optional
- They are fairly large and are not easily moved or damaged
- Can be erected at a repository location or elsewhere
- May be conceived in the form of monuments.
- Offer the opportunity for regular opening ceremonies, giving, at the same time opportunity for re-inspection and updating.
- They can combine transmission with and without intermediaries
- Offer opportunity for federating interests within and beyond the local community
- There exist examples of scientific approaches to construct millennial time capsules with the involvement of society. The know-how for developing a millennial time capsule is fairly accessible.
- Can be linked to local lore and traditions

As for catering to local lore and traditions, the “the sky is the limit”, and it needs to be explored. For instance:

- A municipality decides to place pictures of its people and places of the year *X* plus a letter of the present mayor that explains today’s choices. The pilot time capsule is opened every 33 years.
- Two municipalities will hold similar time capsules and will revisit pilots at different times creating a stronger link amongst municipalities and to the waste repository. They could also decide to have two different types of time capsules<sup>14</sup>.
- An international network of MTCS is created. In each country the MTCS is inspected at a different date.
- Replicas can be placed in several places, e.g., besides its regular collection, the National Archive may also house a time capsule in one of its gardens.
- Etc.

This linking to local lore would create additional momentum towards stimulating future institutional players to respect oversight commitments and carry out further RK&M preservation activities.

### Millennial time capsules at depth (MTCD)

Besides millennial time capsules near surface (MTCS), Pescatore has also proposed a new kind of time capsule. Namely, smaller-size millennial time capsules at depth (MTCD) placed strategically at the repository horizon and/or in the access shafts.

Envisage, as an example (Figure 6), a cylindrical capsule with hemispherical caps with 50-100 liter internal volume, say, and made of the same material as the waste containers or of a more durable material. Information about the repository and aimed at the potential intruder

---

<sup>14</sup> Natural candidates in Sweden are the municipalities of Östhammar and Oskarshamn



could be packed into the capsule, e.g., on long-lasting supports. The capsule would last for at least as long as any waste container. It would constitute the ultimate source of (fairly) detailed information enabling future generations to make their own informed decisions about the waste, should they stumble upon it.

## 5. Conclusions

There is, at present, broad international support to the concepts of not relinquishing oversight of a repository and of providing future generations with meaningful information so that they may make their own informed decisions. In Sweden a similar view was present already in the early 80s when the KBS-3 concept was formulated. Namely, it was said: “It must be assumed that future generations will bear the responsibility for their own conscious actions. *What is of importance in this context is to provide them with the best possible information as a basis for their decisions, i.e. to make sure that information on the location, design and function of the final repository is carefully recorded and preserved. If, at some time in the future, people wish to retrieve and recover the copper or the spent fuel present in the final repository, they will then be aware of and able to cope with the radiological risks.*” [SKBF, 1983] The above KBS position does not necessarily imply additional oversight activities, such as monitoring, etc. once the repository is closed. Yet, a certain amount of attention – and therefore RK&M preservation – would be needed in the course of time in order for records to be kept properly and to remain available and understandable.

The implicit assumption in the KBS-3 quote above and in today’s RK&M preservation approach within and beyond radioactive waste management is that, in the future, appropriate institutions and individuals will have the memory as well as the knowledge, the records and the means to act further, and that the information will be as clear to them as it was to those who left it originally or who re-worked it in the intervening time. This vision of a rolling present is not necessarily realized in practice: archives may disappear or become insufficient, records enabling the memory of why certain decisions were taken may be lost, funds may not be available when needed to perform corrective actions, nor may the relevant information be accessible and understandable. Present preservation intentions may well go unfulfilled in a long-term perspective. This is why intentions should be identified and studied as well as threats to their survival, and strategies for their fulfilling should be devised. This will require a cultural change in present days approaches, which will likely take decades to refine and implement. As seen in the Verdun conference (2014) there is at present good momentum towards starting the reflections both nationally and internationally.

Besides, the recent international recommendations call for continued oversight of the closed repository, which strengthen and go beyond requirements to preserve just records. Oversight or “keeping a watchful eye”, may be more or less direct, and may weaken with time or go through periods of ups and down. Oversight relies on provisions for memory keeping. The ICRP suggests that, beyond the relevant institutions, society at large should also play a role in oversight, e.g., in contributing to RK&M preservation. In the end, the future belongs to all, and all should do their part in preserving options and freedom of choice for future generations. Both national institutions and the local stakeholders concerned with radioactive waste are called to take a position on the ICRP recommendations.

One emerging means to help society preserve records, knowledge and memory is that of creating locally or in different places, millennial time capsules near surface and, as ultimate source of information, millennial time capsules at depth. Both types of time capsules would function in parallel to archives and have the potential to outlast them in terms of records keeping. Millennial time capsules near surface may be conceived as cultural objects and as being part of a host community lore, thus building a long-lasting bridge between that

community and the facility and, possibly, federating communities with similar facilities worldwide. The concept was overlooked in past literature on repository marking and is worth further consideration.

Finally, a methodology needs to be built and implemented that goes beyond the “rolling present approach”. Principles have been formulated and some initial lines of work established for constructing tables of RK&M preservation tools that support those principles. Further work is needed to advance these areas.

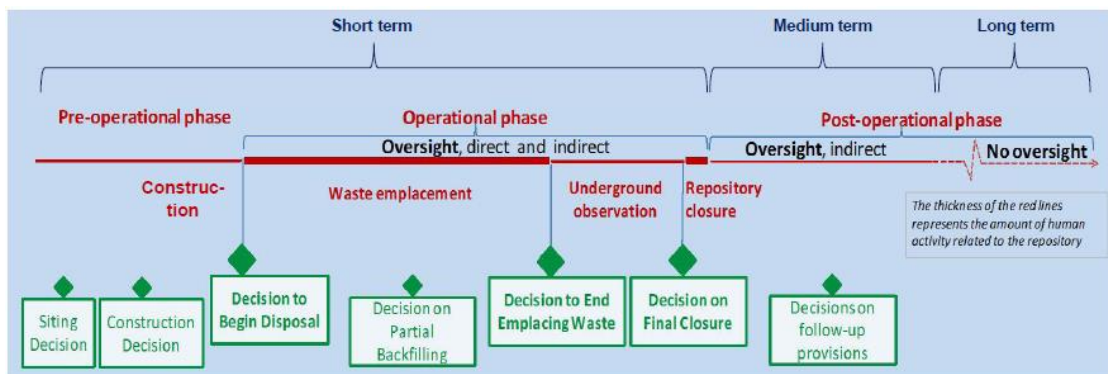
## References

- [IAEA, 1997] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management". The relevant article is Art. 17. The text of the Convention is accessible via <http://www-ns.iaea.org/conventions/waste-jointconvention.asp>
- [ICRP, 2013] International Commission on Radiological Protection, "Radiological Protection in Geological Protection of Long-Lived Solid Radioactive Waste", Authors: W. Weiss, C-M. Larsson, C. McKenney, J-P. Minon, S. Mobbs, T. Schneider, H. Umeki, W. Hilden, C. Pescatore, M. Vesterlind. International Commission on Radiological Protection, Publication 122. Available as: Ann. ICRP 42(3), 2013
- [Linnaeus, 2014] Holtorf, C. and A. Högberg (2014) "Nuclear Waste as Cultural Heritage of the Future." WM2014 Conference Proceedings. Available at <https://www.diva-portal.org/smash/get/diva2:718845/FULLTEXT01.pdf>
- [NEA, 2011] "Reversibility and Retrievability (R&R) for the Final Disposal of High-Level Radioactive Waste and Spent Fuel", NEA/RWM/R/2011(4), December 2011. Nuclear Energy Agency of the OECD. Available via [http://www.oecd-nea.org/rwm/rr/documents/RR-Final-Report\\_GD.pdf](http://www.oecd-nea.org/rwm/rr/documents/RR-Final-Report_GD.pdf)
- [NEA, 2014a] "Radiological Protection and Geological Disposal: The Guiding Principles and Recommendations of the International Commission on Radiological Protection (ICRP)"- A Collective statement of the RWMC, CRPPH and ICRP, published by the OECD/NEA 2014. Nuclear Energy Agency of the OECD. Available as: <https://www.oecd-nea.org/rwm/documents/icrp-rp-gd.pdf>
- [NEA, 2014b] "Foundations and guiding principles for the preservation of records, knowledge and memory across generations: A focus on the post-closure phase of geological repositories", A collective statement of the NEA Radioactive Waste Management Committee. Nuclear Energy Agency of the OECD. Available via <https://www.oecd-nea.org/rwm/rkm/documents/flyer-A4-rkm-collective-statement-en-2014.pdf>
- [NEA, 2014c] "Local Communities' Expectations and Demands on Monitoring and the Preservation of Records, Knowledge and Memory of a Deep Geological Repository", NEA/RWM/R/2013(4), February 2014. Nuclear Energy Agency of the OECD. Available via <https://www.oecd-nea.org/rwm/docs/2013/rwm-r2013-4.pdf>

- [NEA, 2014d] “Markers – Reflections on Intergenerational Warnings in the Form of Japanese Tsunami Stones”, NEA/RWM/R/2014(4), May 2014. Nuclear Energy Agency of the OECD. Available via <https://www.oecd-nea.org/rwm/docs/2014/rwm-r2014-4.pdf>
- [NEA, 2014e] “Loss of Information, Records, Knowledge and Memory – Key Factors in the History of Conventional Waste Disposal”, NEA/RWM/R/2014(3). Nuclear Energy Agency of the OECD. Available via <https://www.oecd-nea.org/rwm/docs/2014/rwm-r2014-3.pdf>
- [NEA, 2015] “Radioactive Waste Management and Constructing Memory for Future Generations”, Proceedings of the International Conference and Debate, 15-17 September 2014, Verdun, France. NEA No. 7259. Available via
- [Pescatore, 2016] Pescatore, C and A. van Luik, “Millennial Time Capsules as a promising means for preserving records for future generations”, WM 2016 Conference Proceedings, Phoenix, AZ
- [SKBF, 1983] Swedish Nuclear Fuel Supply Company / Division KBS, “Final Storage of Spent Nuclear Fuel – KBS-3, Summary”, Stockholm, May 1983
- [van Luik, 2016] Van Luik, A., J-N Dumont, et al., Key Information File for Radioactive Waste Repositories – Preliminary test, WM 2016, WM Symposia, Arizona.

# Figures

Figure 1



**Figure 2.** List of main RK&M tools and their target delivery and efficacy in time

Class of RK&M tool	RK&M tool	Mostly Mediated (M) or Non-mediated (NM)	Records (R), Knowledge (K), Memory (M), Awareness upon discovery (AuD)	Short (ST), Medium (MT), Long (LT) term
Archives	National archives	M	R	ST, MT, LT
	Regional/local archives	M	R	ST, MT
	Land registries	M	R	ST, MT
	Specialized archives	M	R	ST, MT
Libraries	National library	M	R	ST, MT
	regional	M	R	ST, MT
	academic	M	R	ST, MT
	others	M	R	LT
Time Capsules	Large size, visible	NM, M	R, K, M	MT, LT
	large size, non visible	NM, M	R, K, M, AuD	MT, LT
	Small size	NM	R, AuD	MT, LT
Markers	Surface traces	NM	AuD	MT, LT
	Surface markers	NM	M	MT, LT
	Sub-surface markers	NM	AuD	MT, LT
	Monuments	NM	M	ST, MT, LT
Cultural heritage	Local cultural heritage	M	M	MT, LT
	Regional industrial heritage	M	M	ST, MT, LT
	International Heritage	M	M	ST, MT, LT
	Traditions and rituals	M	M	ST, MT, LT
	Local history and enactment societies	M	M	ST, MT, LT
	Endowed Univ. Chair	M	R, K, M	ST, MT
International mechanisms	For controlling radwaste and materials	M	R, K, M	ST, MT
	For sharing knowledge on geology	M	R, K, M	ST, MT
	Related to environmental protection	M		ST, MT
	Related to cultural heritage preservation	M	R	ST, MT
Oversight provisions	Monitoring	M	R, K, M	ST, MT
	intermittent safety reviews	M	R, K, M	ST
	Transfer of responsibilities	M	R, K, M	ST
	Updating key repository documents	M	R, K, M	ST
	Training of personnel	M	R, K, M	ST
	Land use restrictions	M	R, M	ST
	Placing signs on maps	M	M, AuD	ST

**Figure 3: Relationship between RK&M tools in the long-term period**

Class of tool	Tool	Archives	Libraries	Time Capsules			Markers				Cultural heritage				
		National archives	Long term (religious, ...)	Large size, visible	Sub-surface, large size	Small size at depth	Surface traces	Surface markers	Sub-surface markers	Monuments	Local cultural heritage	Regional Industrial heritage	International Heritage	Traditions and rituals	Local history and enactment societies
Archives	National Archives		C	R	R	S	S	S	S	S	S	S	S	S	C
Libraries	Long term (religious, ...)	C		S	S	S	S	S	S	C	C	S	S	R	S
Time Capsules	Large size, visible	R	I		R	S	S	S	S	S	I	I	I	I	I
	Sub-surface, large size	R	I	R		S	S	S	S	S	I	I	I	I	I
	Small size at depth	C	I	S	S		I	I	I	I	I	I	I	I	I
Markers	Surface traces	I	I	I	I	I		I	I	I	I	I	I	I	I
	Surface markers	I	I	S	S	I	I		S	S	I	I	I	I	I
	Sub-surface markers	I	I	I	I	I	I	I		I	I	I	I	I	I
	Monuments	S	C	S	S	I	I	I		I	I	I	I	I	I
Cultural heritage	Local cultural heritage	I	C	S	S	I	S	S	S	S		S	S	S	S
	Regional Industrial heritage	I	S	S	S	I	S	S	I	S	S		S	S	S
	International Heritage	C	S	C	C	I	S	S	I	S	S	S		S	S
	Traditions and rituals	I	R	I	S	I	I	S	I	S	S	S	S		S
	Local history and enactment societies	C	S	S	S	S	S	S	S	S	S	S	S	S	

**R=Redundancy:** When the two strategic components contain redundant records  
**C=Reinforcing:** When the two strategic components contain different records providing similar or complementary information  
**S=Support:** When one of the two strategic components may point to the other one  
**I=Independent:** When one of the two strategic components likely does not relate to the other one

**Figure 4: In the foreground of the Osaka Castle is the plaque recalling the burial of a millennial dual time capsule in 1970. The two time capsules are kettle shaped.**



**Figure 5 . The pilot capsule is unearthed, inspected and re-buried in the year 2000. Each time capsule is embedded in packing materials (bentonite) and a concrete container.**

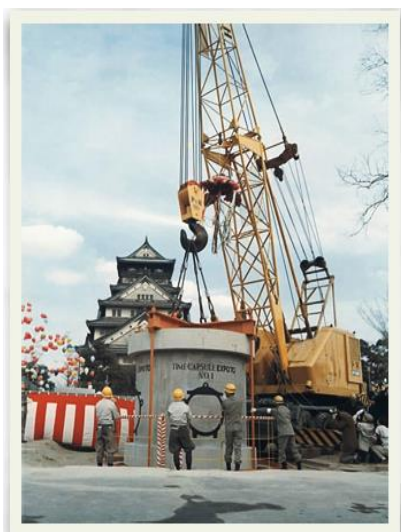
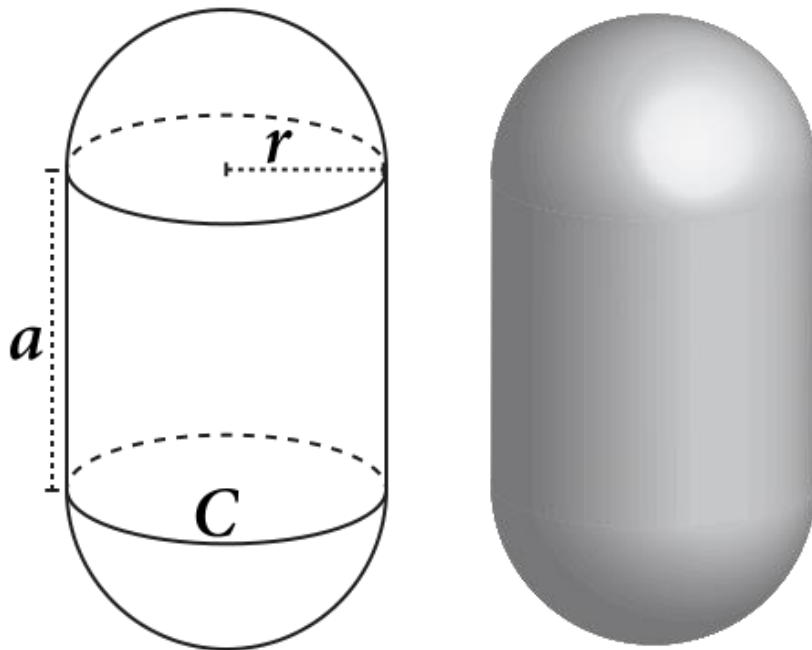




Figure 6 Example of MTCD geometry



## **ANNEX: Key questions and recommendations for potential way forward in the Swedish context**

The followed recommendations are specifically tailored to the Swedish situation, but could be easily generalized internationally. They were formulated having in mind the possibility of organizing a national workshop in Sweden in order to clarify issues and help relevant actors better prepare to address them in a coordinated fashion.

- Check where do we stand, at present, on realizing the KBS-3 position *“to make sure that information on the location, design and function of the final repository is carefully recorded and preserved.”* [SKBF, 1983]
  - Is this still the KBS-3 position? What do “carefully” and “preserved” mean and imply?
  - What are expectations, intentions over the next decades, centuries and beyond?
  - Who is in charge of what institutionally?
  - Which are the identified main preservation issues and potential solutions?
  - What is the expected role of non-institutional actors, e.g., host municipalities?
  - How are the institutional actors acting upon international recommendations and positions?
  - Should consideration be given to setting up a national platform to be collecting and discussing issues?
- Check with Swedish institutions on the questions identified in Chapter 2 of this text. Namely:
  - Does an institutional view exist on informing the upcoming and later generations? Which are the target audiences? What are the periods of time?
  - The present, default strategy most likely is to pass all official documentation on to the national archive: what, then, should be kept and what could be discarded? Would it not be useful to make a selection of documents, taking as well different readerships into account? Who would make this selection? Who would keep updating the info?
  - What if a rolling present is not realized; which RK&M preservation strategies could cope with that? On which time scales?
  - Would it not be wise to connect records keeping with knowledge and memory preservation in a way that society at large may contribute some form of oversight?
- Check with all Swedish stakeholders on the validity of this following statement. Namely *“The future belongs to all, and all interested parties should do their part in preserving options and freedom of choice for future generations. Freedom of choice rests on access to intelligible records, exploitable knowledge and renewed memory of past actions and decisions. It behooves both institutional and non-institutional players to determine what their role should be in preserving RK&M and take relevant, coordinated actions”*.
- Do Swedish municipalities accept that they also have a role to play in informing local future generations on certain decisions made today, on what the subsurface of their community may conceal, etc.? Is local archiving the only or the good solution? What would need archiving? Is local archiving coordinated with other levels of archiving, notably the national archives?
- Are the Swedish actors interested in starting thinking about (a) a dual time capsule near surface; (b) the concept of time capsule at depth?
- Should the above themes, and especially the one on time capsules at depth, be part of the next FUD?
- ... etc