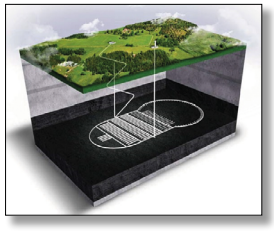
Radioactive Waste Management and Decommissioning
2019

Preservation of Records, Knowledge and Memory (RK&M) Across Generations

Final Report of the RK&M Initiative





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Radioactive Waste Management and Decommissioning

Preservation of Records, Knowledge and Memory (RK&M) Across Generations:

Final Report of the RK&M Initiative

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Cover photos: High Level Radioactive Storage and Treatment Building – HABOG (COVRA, the Netherlands); Artist's impression of a future deep geological radioactive waste repository (COVRA, the Netherlands).

Foreword

Many member countries of the OECD Nuclear Energy Agency (NEA) are engaged in the development of projects for the final disposal of radioactive waste and spent fuel. Disposal facilities will be developed, implemented and operated over many decades and are meant to remain functional for up to hundreds of thousands of years. For high-level, long-lived radioactive waste and spent fuel, geological disposal is the reference management strategy. Such repositories are designed to be intrinsically safe and final: their safety should not rely on human maintenance or intervention. Nevertheless, there is no intention to abandon these repositories or to lose oversight of them. Records, knowledge and memory (RK&M) of the repository and the waste it contains should be preserved as long as possible. Consequently, RK&M preservation, aimed at avoiding inadvertent human intrusion and supporting informed decision making in the future, has been identified as an integral part of responsible radioactive waste management in line with a prudent approach to safety and a conscious attitude to ethics. It constitutes a dedicated management task that is best addressed while waste management plans are being designed and implemented, and while funding is available.

Against the background of increasing demands by waste management specialists and other involved parties for international reflection and progress towards viable and shared strategies in this field, the NEA Radioactive Waste Management Committee (RWMC) launched an initiative on the "Preservation of Records, Knowledge and Memory (RK&M) Across Generations" – the so-called "RK&M initiative" – in 2011. The objective of the initiative was twofold: to develop a theoretically founded, broad-based understanding – technical, managerial, institutional, societal and cultural – of the issue, and to develop a practice-oriented "toolbox" of concrete RK&M preservation methods, a "menu" that will allow people to identify various approaches and mechanisms to develop a strategic action plan for RK&M preservation across generations.

Membership of the initiative was varied with regard to organisations, disciplines and nationalities and included representatives from implementing agencies, regulatory agencies, nuclear research institutes and national archives from Belgium, Canada, the Czech Republic, Finland, France, Germany, Hungary, Japan, Russia, Spain, Sweden, Switzerland, the United Kingdom and the United States (see Annex 4). The International Atomic Energy Agency (IAEA) and the European Commission (EC) also participated. Due to the multidisciplinary nature of the topic, the RWMC also reached out beyond its members for insights from research fields not typically represented in waste management organisations, such as history, archaeology, social sciences and cultural studies. The RK&M initiative ran from March 2011 up to April 2018. This report presents its overall findings.

Acknowledgements

The Nuclear Energy Agency (NEA) would like to thank the many who contributed to the RK&M initiative by participating directly as a member, by taking part in project meetings, workshops or conferences, by responding to project questionnaires, or by providing input to project documentation.

The initiative was initiated and co-ordinated by Claudio Pescatore (former NEA) from the start in 2011 until August 2015, and chaired by Stephan Hotzel (Gesellschaft für Anlagen- und Reaktorsicherheit – Global Research for Safety [GRS], Germany) from September 2015 until the end in April 2018. The RK&M Bureau Members were Arne Berckmans (National Agency for Radioactive Waste and Enriched Fissile Material [NIRAS/ONDRAF], Belgium), Anne Claudel (National Cooperative for the Disposal of Radioactive Waste [Nagra], Switzerland), Jean-Noël Dumont (National Agency for Radioactive Waste Management [Andra], France), Sofie Tunbrant (Nuclear Fuel and Waste Management Company [SKB], Sweden), Simon Wisbey (Radioactive Waste Management – Nuclear Decommissioning Authority [RWM-NDA], United Kingdom) and Abe Van Luik* (Department of Energy [DoE], United States). This final report was prepared by Jantine Schröder (Nuclear Research Centre [SCK•CEN], Belgium).

* Dr Abraham (Abe) van Luik was a key member of the RK&M team, but passed away in July 2016, prior to the report being completed. He is sorely missed.

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List of abbreviations and acronyms

Andra	National Agency for Radioactive Waste Management (France)
D&D	Decommissioning and dismantling
DOE	Department of Energy (United States)
Euratom	European Atomic Energy Community
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit – Global Research for Safety (Germany)
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICT	Information and communication technologies
KIF	Key information file
Nagra	National Cooperative for the Disposal of Radioactive Waste (Switzerland)
NEA	Nuclear Energy Agency
NIRAS/ONDRAF	National Agency for Radioactive Waste and Enriched Fissile Material (Belgium)
OECD	Organisation for Economic Co-operation and Development
PPP	Polluter pays principle
SER	Set of essential records
RD&D	Research, development and demonstration
RepMet	Radioactive Waste Repository Metadata Management initiative (NEA)
RK&M	Records, knowledge and memory
RWM	Radioactive waste management
RWM-NDA	Radioactive Waste Management – Nuclear Decommissioning Authority (United Kingdom)
RWMC	Radioactive Waste Management Committee (NEA)
SCK•CEN	Nuclear Research Centre (Belgium)
SER	Set of essential records
SKB	Nuclear Fuel and Waste Management Company (Sweden)
UNESCO	United Nations Educational, Scientific and Cultural Organization
WIPP	Waste Isolation Pilot Plant

The glossary of terms of records, knowledge and memory (RK&M) preservation

When reading this report and other outcomes of the RK&M initiative, readers are advised to make use of the dedicated glossary of terms of RK&M preservation (hereafter "RK&M glossary"). It is included in Annex 1.

The RK&M glossary defines key terms and concepts used in the RK&M initiative and as such, provides useful guidance on terminology in the area of long-term RK&M preservation for radioactive waste disposal. The terms and concepts in the glossary do not uniquely pertain to the RK&M preservation topic. They are also used in other contexts and international texts, where their meaning may differ. The RK&M glossary definitions thus do not necessarily reflect the most common understanding or use of the terms, but aim at stipulating the respective terms within the RK&M preservation context.

Executive summary

Geological repositories for the final disposal of radioactive waste are currently being developed in many countries. These repositories are designed to be inherently safe over the periods of time that are necessary to protect humankind and the environment against the effects of ionising radiation. The issue of maintaining some information and a degree of awareness of the facilities in the future is a challenge that has been much discussed over the past 50 years. Against the background of ever increasing demands by waste management organisations and other stakeholders for international reflection and progress towards viable and shared strategies in this field, the Nuclear Energy Agency (NEA) Radioactive Waste Management Committee (RWMC) launched an initiative on the "Preservation of Records, Knowledge and Memory (RK&M) Across Generations" – the so-called "RK&M initiative", that ran from March 2011 to April 2018. The initiative aimed at gaining a theoretically founded, broadly based understanding of the issue, leading to the development of a "toolbox" of methods that will eventually be combined into a strategic action plan for RK&M preservation across generations.

To achieve this goal, the initiative focused on five key questions:

- For which reasons and purposes do we need and want to preserve RK&M about radioactive waste across generations?
- What kind of information needs to be maintained?
- Over which timescales?
- By whom and for whom?
- What can be done now and later to provide maximum continuity and accessibility of RK&M?

Key findings and recommendations

In the past, RK&M preservation efforts were mainly directed at avoiding inadvertent human intrusion through messages and methods focusing on danger and promoting aversion. Although deterring potential intruders remains a valid goal, it was found that this should rather be achieved by supporting an informed and alert attitude towards the required levels of safety, security and societal accordance. More generally, supporting informed decision making in the future – including the decision to access the repository and the waste it contains – was identified as an integral part of responsible radioactive waste management. This is in line with recent recommendations issued by the International Commission on Radiological Protection (ICRP), as well as with a prudent approach to safety and a conscious attitude to ethics.

Achieving these objectives can only be done in a manner that combines the preservation of records, knowledge and memory. Indeed, it is not just a question of handing down a message, but of keeping that message interpretable, meaningful, credible and usable over time. Moreover, there is no single approach or mechanism that would achieve, on its own, the preservation of RK&M over all timescales. Therefore, the RK&M initiative compiled a list of 35 mechanisms grouped into 9 broad approaches that are described in detail in this report and include the following:

- dedicated record sets and summary files;
- memory institutions (archives; libraries; museums);

- markers (both above and below the surface);
- time capsules (both with and without opening strategies);
- culture, education and art (e.g. cultural heritage; alternative reuse of the disposal site; education, research and training; works of art);
- knowledge management (e.g. knowledge retention tools; knowledge sharing philosophy);
- oversight provisions (monitoring; clear and planned responsibilities; land use controls);
- international mechanisms (e.g. international regulations and agreements; international inventories and catalogues);
- regulatory framework (national regulatory framework; safeguards).

The first approach in this list, "dedicated record sets and summary files", includes two mechanisms that were developed by the initiative:

- Set of essential records (SER) – a unique set of records, selected during the repository lifetime, together aimed at providing sufficient information for current and future generations to ensure an adequate understanding of the repository system and its performance.
- Key information file (KIF) – a single document, produced in a multidisciplinary and participatory manner, intended to inform present and future stakeholders without specialised knowledge.

A sustainable RK&M preservation strategy will combine a number of mechanisms selected from the above compilation into a system. These mechanisms should have different key characteristics in terms of timescales addressed, media, contents, transmission modes, actors and locations. The mechanisms should be integrated with, or complement, one another, refer to each other and provide for diversity and redundancy, with a view to maximising information accessibility, understandability and survivability. Such a preservation strategy inherently requires to be elaborated in a multidisciplinary and participatory process. In particular, RK&M preservation aims at the societal embedding of the repository by creating a holistic disposal project in which the disposal technology, the site design and the societal environment are integrated and mutually supporting. Examples of strategies can be found in this publication.

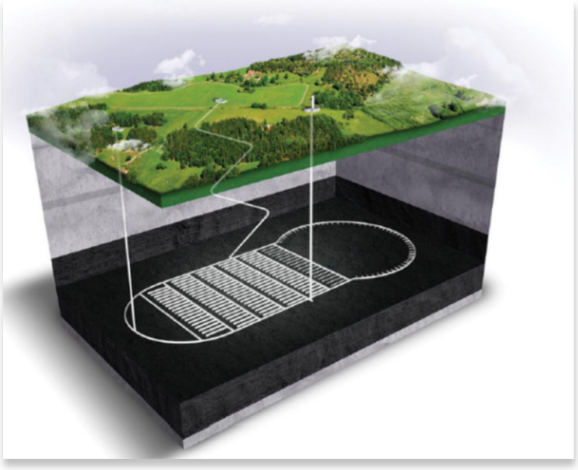
In addition to this publication, deliverables include a reference bibliography, providing a literature overview of work performed in the field of the preservation of RK&M in relation to radioactive waste management, a catalogue of current laws and regulations regarding RK&M preservation in force in various countries and guidelines on the development of both a KIF and a SER.

Chapter 1. **Introduction**

The term "waste" generally refers to things that society considers to be of no value and wants to get rid of. Not all waste can be made to disappear, however. And not all waste is harmless. Historically, approaches to the handling of waste have often been to dump it in an uncontrolled fashion on the basis that the environment has an infinite capacity to absorb, degrade and disperse the waste. However, industrialisation has led to a massive increase in the scale and toxicity of the waste. The environmental movement has also played a significant role in focusing attention on proper waste management.

Since its discovery in the late 19th century, many countries have exploited the processes that define radioactivity. Rapid scientific development and technological application in the industrial, medical and military fields have resulted in the production of a wide variety of radioactive waste. Humans and the environment need to be protected from the radioactivity and toxicity from this waste. For high-level, long-lived radioactive waste and spent fuel, this protection needs to last for periods of time extending to hundreds of thousands of years. The international consensus is that radioactive waste should be managed by isolating and containing it, so that its hazardous nature cannot cause harm to humans and the environment (e.g. EU, 2011; ICRP, 2013). Final disposal facilities are designed to fulfil these functions of preventing or controlling the release and dispersion of radioactive substances by means of a combination of engineered and natural barriers (see also IAEA, 2016) (see Figure 1.1).

Figure 1.1. **Artist's impression of what a future deep geological radioactive waste repository may look like**



Source: COVRA.

The development and implementation of these disposal facilities will take several decades. Once filled with radioactive waste, disposal facilities are to be sealed and closed. In this state they are to remain safe for several millennia. Final radioactive waste disposal repositories are designed to be "intrinsically safe", in such a way that safety does not depend on human presence and intervention, but is provided by the engineered and natural barriers. However, there is no intention to abandon or forget the facilities, nor to forgo, at any time, the records, knowledge and memory (RK&M) of the repository and the waste it contains.

How can we continue to remember and understand across generations where, why and how radioactive waste is disposed? This is the question the RK&M initiative addressed. Deep geological disposal of high-level, long-lived radioactive waste and spent fuel was the reference scenario on which the work of the RK&M initiative was based. However, the initiative's insights and recommendations can also be useful for different types of disposal (e.g. near-surface disposal) and for different types of waste (e.g. low- and intermediate-level radioactive waste, and chemical waste).

1.1. Background and scope of the RK&M initiative

The formulation of a dedicated initiative under the aegis of the RWMC

The question of how to remember and continue to understand where, why and how radioactive waste is disposed of over time was identified as needing dedicated attention by the Nuclear Energy Agency (NEA) Radioactive Waste Management Committee (RWMC). The RWMC is an international committee of senior representatives from regulatory authorities, radioactive waste management and decommissioning organisations, policy-making bodies, and research and development institutions from NEA member countries.[2] The RWMC's mission is to assist NEA member countries in decommissioning and managing all types of radioactive materials, with particular emphasis on the safe management of long-lived waste and spent fuel. To fulfil this aim, the RWMC identifies issues of key importance and concern, and then supports international co-operation to address these issues through various working groups and projects composed of representatives of interested NEA member organisations. The results are documented in reports that function as guidelines for the member states and their respective national radioactive waste management programmes.[3]

Throughout 2007 and 2008, the RWMC identified knowledge consolidation and transfer as key pillars of its modus operandi and work programme. In 2009, two main areas were identified: the first concerned the intra-generational transfer of current and existing information and knowledge to support national programmes; the second concerned intergenerational transfer (i.e. the sharing of information and knowledge across generations). The latter was judged to be of particular importance in light of the exceptionally long time horizons radioactive waste management (RWM) needs to address (NEA, 2009a).

The relevance of these areas was also brought to the fore by the continued and growing importance of certain other topics identified by RWMC and its national members with regard to preparing and implementing disposal projects, such as: reversibility and retrievability; stepwise decision making; flexibility and adaptability; transfer of responsibilities between institutional actors; avoidance of inadvertent human intrusion; and surveillance and monitoring.[4] All these topics depend on the transfer of information to future generations. The need for dedicated attention was also set against the background of national and international policy frameworks and regulatory provisions which explicitly favour the continuation of awareness and knowledge of the location of repositories and the nature of their content over time (EU, 2011),[5] but provide limited actual guidance on the topic. Various national members had also received this request from local communities which host, or may possibly host, a disposal facility (NEA, 2015b).

2. The International Atomic Energy Agency (IAEA) participates in the work of the RWMC, and the European Commission is a full member of the committee. The RWMC also maintains strong ties with national high-level advisory bodies to governments and transnational bodies, such as the International Commission on Radiological Protection (ICRP).
3. See www.oecd-nea.org/rwm/#rwmc.
4. See the NEA Forum on Stakeholder Confidence (FSC) (www.oecd-nea.org/rwm/fsc) and the NEA Reversibility and Retrievability (R&R) Project (www.oecd-nea.org/rwm/rr).
5. The Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, Article 12(e): "[National programmes should include…] concepts or plans for the post closure period of a disposal facility's lifetime, including…the means to be employed to preserve knowledge of that facility in the longer term."

Implementers and regulators were thus found pressed not only by their own needs, but also by the demands expressed by both policy makers and the wider public to show that information and memory transfer is on their agenda (NEA, 2009b).

Against this background, in 2009 the idea of establishing a dedicated, interdisciplinary initiative on long-term preservation of information and memory for geological disposal of radioactive waste was proposed (NEA, 2009b). A questionnaire was prepared to investigate RWMC members' interest, existing activities and national frameworks related to this field. Responses were provided by implementing agencies and regulators from 12 countries (NEA, 2010) and enabled the RWMC to preliminarily identify some key challenges:

- How to reduce the very large amounts of information produced throughout the research, development and demonstration (RD&D) phase to the required level without being overwhelming.
- How to deal with the fact that societies evolve over time, which implies that not only the information needs to be maintained, but also its meaning and relevance.
- How to address the threat that any sort of marking may attract people to the facility in other ways than just for keeping memory.

In 2010, on the basis of topical RWMC sessions and responses to the questionnaire, the relevance of a shared, broad-based and documented understanding at the international level about concepts and methods for the long-term preservation of information and memory was established. Because of the experience accumulated by the advanced national programmes represented, the breadth of initiatives covered, and its multi-discipline and multi-affiliation composition, the forum provided by the RWMC was identified as an appropriate venue to develop such an understanding (NEA, 2011a). The project was officially launched in March 2011.

A Project Advisory Group was set up to develop a project vision (NEA, 2011a) and a collective statement (NEA, 2011b) outlining the rationale for dedicating attention to long-term information and memory preservation, as well as the project's objectives:

> Disposal of long-lived radioactive waste in engineered facilities built in stable, deep geological formations is the reference means for permanently isolating the waste from the biosphere. Although this management method is conceived to be intrinsically safe and final, i.e. not depending on the presence and intervention of man for fulfilling its safety goal, there is no intention to forgo, at any time, knowledge and awareness either of the repository or of the waste that it contains (NEA, 2011a).
>
> Preservation of Records, Knowledge and Memory (RK&M) across generations is needed to support lengthy and complex decision-making processes across long operational and post-operational lifetimes of radioactive waste repositories. It is a recognised management task that spans unprecedented time horizons in which technical, scientific, societal and cultural information is interwoven. […]
>
> Experience indicates that RK&M need to be actively managed from the start of the waste management programmes. Individual programmes show initial progress, but there is a need to internationalise the thinking, compare approaches, test potential solutions and build common references. […] A "systemic" approach should be engaged whereby the various components of the system complement each other, provide for redundancy of message communication, and maximise the survivability of a recognisable message.
>
> The international RK&M project of the NEA/RWMC aims at helping disposal programmes to advance plans and adopt best practices in preserving relevant records, knowledge and memory across generations (NEA, 2011b).

Modus operandi of the RK&M initiative

The RK&M initiative was set up with the financial and human resources of interested organisations of NEA member countries. It was agreed that the work would be done by people from these organisations (see Annex 4 for the list of members), with input from invited experts

and hired consultants. Until 2015, the project was co-ordinated by the NEA and steered by the RWMC Bureau. To further guide and structure the work, in September 2015 the functions of chair and core group or "bureau" were established and filled by elected project members. Project administration was provided by the NEA.

Overall, the initiative was developed in three stages: scoping the issue and identifying key challenges, broadening the understanding, and consolidating lessons learnt and disseminating the initiative's findings and results to different communities (NEA, 2011a).[6] On average two project meetings per year with all project members took place, to present and discuss the work done and to be done in between the meetings.[7] Especially in the first stage of the initiative, literature reviews (see Section 1.2 for a historical review) and surveys (questionnaires sent out to project members and beyond)[8] were important research methods. Due to the multidisciplinary nature of the topic and the acknowledgement that RK&M preservation is not only a technical but notably a social challenge, it was understood that the RWMC would also have to reach out beyond its members, as the new reflections would have to incorporate lessons learnt in research fields not typically represented in waste management organisations, such as history, social sciences and cultural studies. Against this background and in order to further investigate specific themes, workshops with invited outside specialists were organised (such as archivists, archaeologists, cultural heritage specialists and artists), as well as an international conference with invited speakers and a broad outreach.[9] As such, over the years, the RK&M initiative became a reference community for ideas, aspirations and practices in the area of radioactive waste disposal related RK&M preservation.

Key questions and objectives of the RK&M initiative

The following key questions were identified as drivers of the RK&M initiative (NEA, 2011a):

- For which reasons and purposes do we need and want to preserve RK&M about radioactive waste across generations? (why?)
- What kind of information needs to be maintained? (what?)
- Over which timescales? (when?)
- By whom and for whom? (who?)
- What can be done now and later to provide maximum continuity and accessibility of RK&M? (how?)

It was accepted that answering all these questions in an exhaustive, definitive manner would be impossible. RK&M preservation is context dependent and describing RK&M preservation over the various timescales of interest inevitably involves a large degree of abstraction. The objectives of the initiative were thus set up as follows (NEA, 2009b): Firstly, to develop a theoretically founded, broad-based understanding (technical, managerial, institutional, societal and cultural) of the issue at stake (covered in Chapters 1 to 4 of this report). And secondly, to develop a practice-oriented

6. Administratively, the project was divided into two phases: phase I from March 2011 to March 2014 and phase II from April 2014 to April 2017 with an extension to 30 April 2018.
7. Project meetings took place at the NEA premises in Paris. On one occasion project members combined a project meeting with a study visit and gathered in Wick (Scotland) at Nucleus: The Nuclear and Caithness Archives (www.highlifehighland.com/nucleus-nuclear-caithness-archives).
8. The following surveys were undertaken by the RK&M initiative during the first stage: 2010 Survey on Status and Needs; 2011 Survey on Responsibilities; 2011 Survey on Examples of Memory Loss; 2012 Survey with questions of Regulatory Significance (focused on the national implementation of the European Waste Directive); 2012 Survey on RK&M and the Safety Case (distributed to the NEA IGSC); 2012 Survey on Safeguards; 2012 Survey on Relationship with National Archives; 2012 Survey on Costs Associated with Loss of Records, Knowledge and Memory in Decommissioning.
9. The first workshop, "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue", took place in October 2011 (NEA, 2012). The second workshop, "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding", took place in September 2012 (NEA, 2013). The international "Constructing Memory" conference took place in September 2014 (NEA, 2015a).

"toolbox" of generic yet concrete RK&M preservation approaches, a menu-driven document that will allow people to identify the mechanisms of a strategic action plan for RK&M preservation across generations (covered in Chapters 5 and 6 of this report).

A product and process-oriented initiative

Throughout the development of the initiative's vision and terminology, the project's title was changed from the initially proposed "Long-term Preservation of Information and Memory" to "Preservation of Records, Knowledge and Memory (RK&M) Across Generations". This may seem an unduly long project title, but for good reason. The issue under consideration is not only about keeping information as such, but about preserving selected data and information that has been committed to a medium and accompanied by the appropriate context and structure for later uses (records). Moreover, records in themselves have limited meaning without the ability to understand and utilise the data and information they carry (knowledge). In order for this combination of records and knowledge to be transferred across generations, in whatever form and detail, there needs to be awareness of their existence and the reason for their existence, which is supported by a broader awareness of events, people, places and levels of knowledge in the past (memory) (see Annex 1: RK&M glossary).

It was thus acknowledged early on within the RK&M initiative that preservation of RK&M is not only about (final) outcomes (e.g. an archive, a marker, or more generally speaking the records we collect, the things we know, the memories we have), but as much about (ongoing) processes (recording, knowing and memorising) (Schröder and Pescatore, 2012). The change from "long-term" to "across generations" in the project's title did not mean a focal shift in time, but highlights this societal process-character of RK&M preservation (see also Chapter 4 on key characteristics).

The fields of application and target audiences of the RK&M initiative

While significant challenges exist today with regard to operational knowledge management, the focus of the RK&M initiative was on maintaining RK&M for the post-closure phase of waste disposal facilities. Although it was highlighted that RK&M preservation starts today and needs to be acted upon in the decades leading up to repository closure, the focus was thus not so much on contemporaneous needs within nuclear organisations, but on supporting future generations within society. The present operational challenge of dealing with the very large amounts of information produced throughout the planning, development and implementation phases of disposal projects became the focal topic of a separate initiative established in 2014, called "Radioactive Waste Repository Metadata Management" (RepMet) (www.oecd-nea.org/rwm/igsc/repmet). Knowledge management remained part of the RK&M project, although not as a goal on its own, but as one approach among others to serve the goal of RK&M preservation across generations (see Section 5.7 on knowledge management).

In sum, the focus of the initiative was preserving RK&M for the future post-closure phase of repositories for the final disposal of radioactive waste. While deep geological disposal of high-level, long-lived radioactive waste and spent fuel was the reference scenario on which the RK&M initiative's work was based, the initiative's insights and recommendations may also be useful for different types of disposal (e.g. near-surface disposal) and for different types of waste (e.g. low- and intermediate-level radioactive waste and chemical waste). In other words, the insights of the RK&M initiative are relevant for any context in which the question "how can we continue to remember and understand across generations where, why and how hazardous waste is disposed?" is pertinent (see also Chapter 2 on fundamentals).

Keeping in mind the formerly outlined delineations, this report and the other RK&M initiative deliverables are written primarily with an audience of specialists with a formal responsibility in the field of RWM in mind (whether in RD&D, implementation, regulation or policy making). The overarching target audience are all individuals involved in, affected by or interested in RWM. A third audience consists of individuals interested and involved in the broad field of RK&M preservation across generations, regardless of its application (see also Section 4.6 on actors).

1.2. Evolutions in RK&M preservation thinking: A historical review

The attention for RK&M preservation in the framework of radioactive waste disposal is not new. The idea of "communicating with the future" became compelling to various actors as soon as the necessity of long-term RWM came to the foreground, notably from the 1970s onwards. Ever since that time it has been addressed in the literature, including: professional (e.g. reports from nuclear organisations), academic (e.g. articles in scientific journals) and more popular (e.g. opinion pieces in magazines, newspapers and blogs). Throughout the duration of the RK&M initiative, group members compiled an "RK&M bibliography" for an overview of the former two literature categories and kept a close eye on the latter. These tasks helped the RK&M project participants identify topics of concern, focal trends and lessons learnt in radioactive waste-related RK&M literature.

The RK&M reference bibliography

The RK&M reference bibliography[10] (NEA, 2018) aims at providing a literature overview over work performed in the field of the preservation of RK&M in relation with RWM, especially disposal. It includes references to professional and (semi)scientific papers, reports, articles, books and other materials that bear on the subject matter. The list was continually updated by the RK&M initiative members. The oldest reference in the RK&M bibliography dates back to 1972 and the most recent references are from 2018. By the end of the RK&M initiative, the bibliography contained over 200 references to publicly available materials.[11] The language focus was English, but a number of relevant documents in French, German and Swedish were also identified. The bibliography can be accessed at: www.oecd-nea.org/rwm/rkm.

The compilation of the bibliography confirmed that the main discussion terms within radioactive waste-related RK&M preservation thinking have been established in pioneer works steered by RWM organisations from the United States and the Nordic countries in the 1980s and 1990s (L. Aparicio in NEA, 2012: pp. 67-68). RK&M preservation notably came to the foreground as a potential means to prevent or deter inadvertent human intrusion. Two reactions could be discerned (Idem). One perspective, developed mainly by the Nordic countries (see notably Jensen, 1993), focuses on the creation of a mediated communication link to the future, via the next generations (e.g. through institutional RK&M transfer mechanisms). The second, developed mainly in the United States (see notably Trauth et al., 1993), emphasises the long term and the creation of a direct link to future generations, over the next generations, through more technical RK&M devices (notably markers). This distinction was found relevant within the RK&M initiative, which used the terms "mediated" and "non-mediated" transmission of information that further developed into the idea of a "dual-track strategy" (see Annex 1: RK&M glossary and Section 4.5 on multiple transmission modes).

Overall it was found that since the publications by the American and Nordic pioneers, a body of literature on the topic of RK&M preservation has become available, principally produced or commissioned by professional national and international nuclear institutions in the form of reports. An analysis of the bibliography revealed that, overall, a significant portion of the existing references deals with one of two main topic areas:

- preservation of RK&M for short-term,[12] primarily operational purposes;
- long-term preservation of RK&M aimed at notifying future generations about the existence of and hazards posed by a geologic repository.

10. www.oecd-nea.org/rwm/docs/2011/rwm2011-13-rev5.pdf.
11. Hard copies of the documents in the bibliography are also maintained at the Nagra library in Switzerland, which, as a RK&M project member, led the bibliography compilation.
12. Please consult the RK&M glossary (Annex 1) and Figure 4.1 for the use of the reference timeframes short/medium/long term.

Documents in the first group, with the IAEA as an important author, notably deal with knowledge management and record systems, with a focus on the needs of the nuclear industry in the short term. They often contain analyses of a fairly detailed and specific nature of the kinds of information needed and how that information should be collected and organised.

On the other hand, documents in the second group, the main group of interest for the RK&M initiative, are often more theoretical and more abstract. This finding perhaps reflects the fact that most geological repository programmes have not yet reached the point of implementation and have therefore not yet felt the need to develop practical methods for preserving RK&M across generations. This finding guided the work of the RK&M initiative and confirmed the idea of having an inspirational "toolbox" or "menu" of practical mechanisms for RK&M preservation as one of the important outcomes of the initiative (see Chapters 5 and 6 and Annex 2.2/2.3 with the mechanism description sheets).

The majority of documents in the bibliography thus deal with either the short, operational term, or with an undefined, hypothetical long term. Relatively few documents attempt to cover both areas of interest, or to bridge them (by elaborating what the RK&M initiative refers to as "the medium term"). For example, limited work was available on themes such as contextualising data for later use, systematic identification of mechanisms for RK&M transfer over different timescales, or the transfer of responsibilities over time.

The analysis of the bibliography also revealed specific topics that have not been widely addressed in previous literature (see also NEA, 2013: pp. 51-56). These topics include costs and funding for activities related to RK&M preservation (see Section 3.4 on costs and funding), the role of actors other than implementing agencies and regulators in RK&M preservation (such as non-governmental organisations, local communities and private bodies) (see Section 4.6 on actors), the role of monitoring in both the creation and preservation of RK&M (see Section 5.8 on oversight provisions), and security and safeguards as motivations for preserving RK&M (see Section 5.10 on the regulatory framework).

Lastly, an inspection of the abstracts ordered by date (ranging from the 1970s and 1980s to the present) suggested that there has been a change in emphasis, or more broadly, a change in the rationale for RK&M preservation across generations. Traditional approaches were based on the premise that safety was best assured by avoiding societal interest in the disposal facility. RK&M preservation mechanisms were designed to enforce this premise, such as land use restrictions enforced by fences for the shorter term and warning markers for the longer term. In recent years more thought has been dedicated to dynamic mechanisms that involve society, such as conditional reuse of sites and active participation by local communities in decision making. Moreover, the idea of "dictating" the future has lost ground in the literature. A more present-day thought is that rather than attempting to manipulate the emotions of future generations, RK&M preservation mechanisms ought to try to simply inform those generations (A. Van Luik in NEA, 2012: pp. 88-89; see also Chapter 2 on fundamentals).

Popular themes in RK&M preservation literature

The broad theme of "how to inform the future about our radioactive waste" sporadically appears in more popular literature and other media, such as opinion pieces, reportages or commentaries in magazines, newspapers, blogs, documentaries and films.[13] Certain themes from the past persistently reoccur in such media, such as the Landscape of Thorns, the Atomic Priesthood and the Ray Cat. They have their origins in literature covered in the RK&M bibliography, but the broader content of these often voluminous sources is habitually omitted in popular media.

13. To give some examples encountered throughout the RK&M project's duration: the films "Into Eternity" (M. Madsen, 2010) and "Containment" (R. Moss and P. Galison, 2015); www.theguardian.com/environment/shortcuts/2017/jan/08/colour-changing-cats-warn-radioactive-waste-nuclear-plants-distant-descendants; www.damninteresting.com/this-place-is-not-a-place-of-honor; http://mentalfloss.com/article/27476/ray-cats-artificial-moons-and-atomic-priesthood-how-government-plans-protect-our (last accessed in February 2018).

Landscape of Thorns

The majority of the US documents in the RK&M bibliography relate to the Waste Isolation Pilot Plant (WIPP), a currently operational deep geological disposal facility in the state of New Mexico. When the WIPP was conceived in the 1980s, two dedicated multidisciplinary panels were convened by the United States Department of Energy. The first panel focused on future inadvertent human intrusion scenarios (the "Futures Panel", see Hora et al., 1991), the second used the insights from the first on markers (the "Markers Panel", see Trauth et al., 1993). Their core recommendation was a dire warning in a number of languages and symbolic warning objects. The panels were insistent on ominous markers and messages conveying a negative tone to cause fear or foreboding (A. Van Luik in NEA, 2012: pp. 88-89). The "Landscape of Thorns", a concept to cover the future WIPP site with giant spikes sticking out in odd directions, remains one of the most illustrative and well-known examples of this approach (see Figure 1.2). A direct communication mode was sought that is "non-linguistic, not rooted in any particular culture, and thus not affected by the expected certain transformation of cultures" (Trauth et al., 1993: p. F-49). The tone for the entire landscape was meant to be non-natural, ominous and abhorrent ("This place is not a place of honor", "What is here is dangerous and repulsive to us"). Future generations were thus notably conceived as "potential intruders", and the question "How will we protect future generations?" consequently translated to "How to warn them off the site?" (Benford, 2000).

Figure 1.2. **Landscape of Thorns**



Source: Concept by Michael Brill and art by Safdar Abidi (Trauth et al., 1993: p. F-61).

Perhaps because the reports of the panels are so rich in definite and often rather spectacular proposals, there is a risk of overlooking their more generic insights, the grounding thoughts behind the various marker proposals. For one, the recommendation was formulated to create not one sole marker, but a "marking system". By this, the panellists meant a combination of message levels, marking system components, materials and modes of communication in which the "components relate to one another in such a way that the whole is more than the sum of its parts" (Trauth et al., 1993: p. F-11). More generally, a "systems approach" was defended, "where the various elements of the communications system are linked to each other, act as indexes to each other, are co-presented and reciprocally reinforcing" (Trauth et al., 1993: p. F-33). This approach was found fundamentally valuable within the RK&M initiative and was elaborated beyond the mechanism of on-site markers alone (see Annex 1 and Chapter 6).

Another key concept in the Marker Panel's report found pertinent within the RK&M initiative is redundancy. The panel defined this concept as an RK&M preservation strategy "where some elements of the system can be degraded or lost without substantial damage to the system's

capacity to communicate" (Trauth et al., 1993: p. F-33). It was further stipulated that redundancy, important to message survivability, should be achieved through: (a) a high frequency of message locations, permitting some to be lost; (b) making links among message levels; and (c) multiple and mutually reinforcing modes of communication (Ibidem: p. F-50).

Atomic Priesthood

Perhaps one of the first references to the challenge of RK&M preservation dates back to 1972, when the well-known nuclear engineer A. Weinberg connected nuclear energy to a demand for "a vigilance and a longevity of our social institutions that we are quite unaccustomed to" (Weinberg, 1972: p. 33). Weinberg introduced the notion of a long-term nuclear "priesthood", albeit in the context of long-term safeguards (Ibidem: p. 34). This concept was later developed further and applied to long-term RWM by Th. Sebeok, a semiotician and linguist who was one of the consultants within the "Human Interference Task Force". Convened by the US DOE in 1981, this was the first multidisciplinary panel (preceding the Futures and Markers panels) tasked to find ways to reduce the likelihood of unintentional intrusion, focusing on the proposed Yucca Mountain disposal site. The task force consultants concentrated on long-term communication and established the field which would become known as "nuclear semiotics", with Sebeok as a leading figure.[14]

Sebeok imagined a system of "legend-and-rituals" around an "Atomic Priesthood", whose task it would be to keep the knowledge of nuclear waste alive yet secret. The idea comes down to creating superstition among the "uninitiated" and reserving the truth about the disposal site for a "priesthood" of academics, which would select its own members as a self-perpetuating intellectual oligarchy (Wikander, 2015: p. 115). As Sebeok explained:

> The legend-and-ritual […] would be tantamount to laying a "false trail", meaning that the uninitiated will be steered away from the hazardous site […]; essentially, the reason would be accumulated superstition to shun a certain area permanently. […] The actual "truth" would be entrusted exclusively to – what we might call for dramatic emphasis – an "atomic priesthood", that is, a commission of knowledgeable physicists, experts in radiation sickness, anthropologists, linguists, psychologists, semioticians, and whatever additional expertise may be called for now and in the future. Membership in this "priesthood" would be self-selective over time. (Sebeok, 1984: p. 24)

Unsurprisingly, Sebeok is principally remembered for his "nuclear priesthood" notion. He developed two other ideas that were found to be of more relevance within the RK&M initiative. Sebeok recommended a "relay system", "dividing the 10 000 year epoch envisaged into manageable segments of shorter, and presumably, reasonably foreseeable periods" planning no more than three generations ahead and including a plea for updates (Sebeok, 1984: p. 26). In his legend-and-ritual approach, Sebeok also recommended redundancy by deploying both written and oral traditions, and more generally, "as many stable systems and devices be utilised as imagination suggests and technology permits" (Ibidem: p. 21).

14. Sebeok first coined the notion of "nuclear priesthood" in the Human Interference Task Force sub-report "Communication Measures to Bridge Ten Millennia" (Sebeok, 1984: notably pp. 24-28). Upon the publication of the final report of the task force (Human Interference Task Force, 1984), interest in "nuclear semiotics" grew and spread. In 1984, the German journal *Zeitschrift für Semiotik* (*Journal of Semiotics*) published a special edition with a dozen responses from academics to a poll asking how to communicate across 10 000 years ("Und in alle Ewigkeit: Kommunikation über 10 000 Jahre: Wie sagen wir unsern Kindeskindern wo der Atommüll liegt?" ["And into Eternity… Communication over 10 000s of Years: How Will We Tell our Children's Children Where the Nuclear Waste is?"] (www.semiotik.tu-berlin.de/menue/zeitschrift_fuer_semiotik/zs-hefte/bd_6_hft_3). Sebeok contributed to the journal with his most known article "Die Büchse der Pandora und ihre Sicherung: Ein Relaissystem in der Obhut einer Atompriesterschaft" ["Pandora's box and its protection: A relay system in the care of an atom priesthood"]. It became further known when published in a book edited by R. Posner in 1990: *Warnungen an die ferne Zukunft – Atommüll als Kommunikationsproblem* (*Warnings to the Far Future – Atomic Waste as a Communication Problem*) (Posner, 1990).

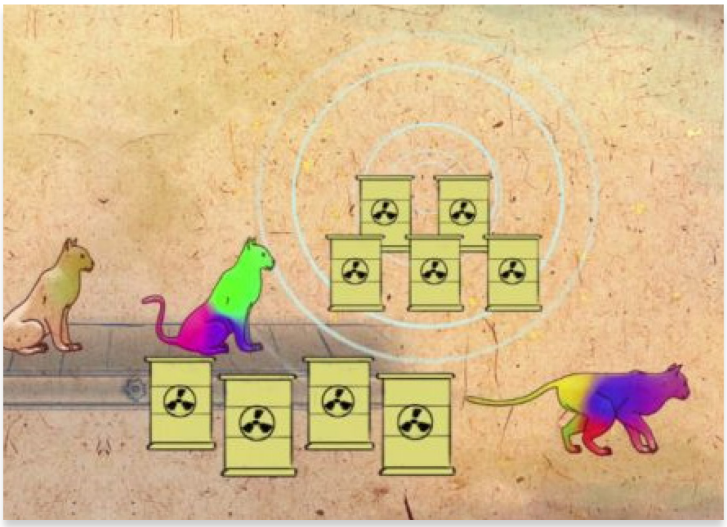
The Ray Cat

Philosophers F. Bastide and P. Fabbri also responded to the 1984 poll asking how to communicate across 10 000 years (see Footnote 14). Their proposal consisted of two steps:

1. Engineer a cat that changes colour in response to radiation.
2. Create a culture around this cat, such that if your cat changes colour, everybody knows you should move someplace else.

Ray cats would be genetically modified as to change colour when coming near to radioactivity, thus serving as living indicators of danger (see Figure 1.3). The choice for a cat was due to their long history of cohabitation with humans. In order to transport the message, the importance of the cats would need to be set in collective societal awareness. To this aim, Bastide and Fabbri proposed storytelling and myths, which could be transmitted through poetry, music and painting. As such, the meaning of the "feline Geiger counter" should spread and become culturally embedded over time.

Figure 1.3. **Image from the documentary "The Ray Cat Solution"**



Source: Benjamin Huguet (2015).

While, unsurprisingly, only the Ray Cat itself is commonly remembered from Bastide and Fabbri's proposal, what was found particularly interesting within the RK&M initiative is the combination of tangible and intangible elements and of non-mediated and mediated transfer approaches. Apart from the disposal facility and the radioactive waste itself, it combines a tangible component that is directly transmitted (the cat) and an intangible socio-cultural component that indirectly transfers the meaning of the cat through mechanisms such as storytelling, rituals and songs.

Summary of lessons learnt from the historical review

A rather large array of mechanisms have been proposed in RK&M literature, ranging from markers to archives to "stewardship" ideas, with attention for both organisational (e.g. related to knowledge management) and technical aspects (e.g. the durability of information carriers). A review of popular media coverage of the topic revealed that this breadth of research is often not reflected in this type of literature. Here, only the most spectacular ideas hinged upon the early focus on danger and promoting aversion survive. The most popular formulation of the issue is one along the following lines: How can we possibly communicate such a peril to a future

that lies 10 000, 100 000 or a million years ahead of us? In times in which our language will no longer be understood, should we focus on signs and monuments inspired by primitive art, science fiction inspired robots or genetically modified animals, or on a secret nuclear priesthood that would transfer nuclear knowledge esoterically?

Not only have such presentations highlighted the issue at hand as an insurmountable challenge, they may also have caused it not to be taken up seriously within the field of RWM RD&D (i.e. characterised by scientific rigour and seriousness) and to be shunned by nuclear regulators and policy makers looking for straightforward and controllable policy measures. A focus on short-term knowledge and records management in the sector (see above) and the overall limited availability of regulatory guidelines dedicated to RK&M preservation across generations (see Section 3.2 on RK&M loss and Section 3.3 on regulatory context) perhaps reflect this finding.

On the positive side, the topic's challenging nature and imaginary appeal has attracted a multiplicity of disciplines otherwise not involved in nuclear research (e.g. from the arts and humanities). Also, it has attracted the public's attention and created a broader awareness and dialogue about the issue of long-term RWM. The Ray Cat is exemplary in this regard. Although the original scientific article (published only in German) almost got lost, recently the metaphorical power of the Ray Cat regained attention after it was picked up by a New York radio reporter.[15] Through podcasts, blogs and social media, his work spread rapidly and led to a wide array of creative practices on "Ray Cat folklore", including a documentary,[16] a song,[17] Ray Cat t-shirts,[18] and bottom-up scientific research[19] (referred to as "citizen science" or "do-it-yourself" science; see also Section 5.8 on oversight provisions). As such, Bastide and Fabbri achieved their goal after all. Their proposal was perhaps less about engineering the actual Ray Cat, and more about creating a symbol meant to achieve maximal awareness and reflectivity about the existence of radioactive waste and the challenge of RK&M preservation in society.

A review of professional and (semi)scientific papers, reports, articles, books and other materials, as gathered in the RK&M bibliography, revealed that pioneer work was conducted by the United States and the Nordic countries throughout the 1980s and 1990s. Some of the insights from these reports remain valid and relevant today, but were never elaborated or developed due to reasons not only connected to their content.

The early US reports stand out because of their "futurology" (i.e. societal predictions for thousands of years) on the one hand, and the concrete, often quite spectacular proposals, notably on scary marker concepts, on the other. This caused the reports to not be forgotten, but also, at least in part, to have their foundational content not be taken seriously (e.g. the systems approach or redundancy).

The Nordic studies, on the other hand, stand out because of the thoroughness of their theoretical analysis. The final report for instance, introduces what is referred to as a "dual-track strategy" within the RK&M initiative (see Annex 1: RK&M glossary and Section 4.5 on transmission modes): "two main strategies exist for long-term information transfer, one which links information through successive transfers of archived material and other forms of knowledge in society, and one – such as marking the site with a monument – relying upon a direct link from the present to the distant future. Both strategies may be used, depending on site-specific circumstances" (Jensen, 1993: p. i). The report emphasises that markers alone will not suffice, as lessons from the past show that they may not last and their messages may pose interpretation problems. It also highlights the need for working on an international level, keeping in mind the irrelevance of national boundaries in the long term. Also, it reflects a preference to base RK&M preservation efforts on the right to information about environmental hazards, rather than on simply warning people off by imposing restrictions near the site, the

15. See https://99percentinvisible.org/episode/ten-thousand-years.
16. The Ray Cat Solution by Benjamin Huguet (2015), made in collaboration with Andra in the framework of its competition "Regards sur les déchets radioactifs", www.benjaminhuguet.com/the-ray-cat-solution.
17. "Don't Change Color, Kitty" on the EP "10,000-Year Earworm to Discourage Settlement Near Nuclear Waste Repositories", www.youtube.com/watch?v=g78hZIEqONM.
18. See www.theraycatsolution.com.
19. E.g. Bricobio, a Canadian-based Makerspace and Independent Community for Biology, Art and Science.

latter being regarded as unrealistic in the long term (see also Setzman, 2014). In comparison to its American counterparts, the Nordic report, detached from a definite repository, mainly stays on a generic, theoretical level, and perhaps also due to that reason lacks some of the appeals to the imagination and creativity so abundantly present throughout the US reports.

Overall, the lessons from the historical review shaped the RK&M initiative's outline as follows: refraining from futurology, yet encouraging long-term and creative thinking; focusing RK&M preservation efforts on informing, not on scaring future generations; and combining thorough, multidisciplinary theoretical reflections with a systemic identification of various actual mechanisms for practicable implementation.

1.3. References

Benford, G. (2000), *Deep Time: How Humanity Communicates Across Millennia*, HarperCollins, New York.

EU (2011), Council Directive 2011/70/EURATOM of 19 July 2011 "Establishing a Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste", Official Journal of the European Union, 2 August 2011 (L 199/48).

Hora, S.C., D. von Winterfeldt and K.M. Trauth (1991), *Expert Judgement on Inadvertent Human Intrusion into the Waste Isolation Pilot Plant*, SAND90-3063 UC-721, prepared by Sandia National Laboratories for the US Department of Energy, Albuquerque, New Mexico and Livermore, California.

Human Interference Task Force (1984), *Reducing the Likelihood of Future Human Activities that Could Affect Geologic High-level Waste Repositories*, BMI/ONWI-537, ON: DE84013725, Battelle Memorial Inst., Office of Nuclear Waste Isolation, Columbus.

IAEA (2016), *IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection* (2016 Revision), IAEA, Vienna.

ICRP (2013), *Radiological Protection in Geological Disposal of Long-Lived Solid Radioactive Waste*, ICRP Publication 122, Annals of the ICRP, Vol. 42/3, pp. 1-57.

Jensen, M. (1993), *Conservation and Retrieval of Information – Elements of a Strategy to Inform Future Societies about Nuclear Waste Repositories*, NKS, Roskilde.

NEA (2018), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Reference Bibliography*, OECD, Paris.

NEA (2015a), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate*, OECD, Paris, www.oecd-nea.org/rwm/pubs/2015/7259-constructing-memory-2015.pdf.

NEA (2015b), *Fostering a Durable Relationship between a Waste Management Facility and its Host Community: Adding Value through Design and Process – 2015 Edition*, OECD, Paris.

NEA (2013), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding", www.oecd-nea.org/rwm/reports/2013/rwm-r2013-3.pdf.

NEA (2012), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue: Workshop Proceedings", www.oecd-nea.org/rwm/docs/2012/rwm_r_2012_6.pdf.

NEA (2011a), "Vision for the RWMC Project on Preservation of RK&M Across Generations", NEA/RWM(2011)6/REV2, www.oecd-nea.org/rwm/rkm/#docs.

NEA (2011b), "Preservation of Records, Knowledge and Memory across generations: A Collective Statement of the NEA Radioactive Waste Management Committee (RWMC)", www.oecd-nea.org/rwm/rkm/documents/rkm-collective-statement-2011-en.pdf.

NEA (2010), "2010 Survey on Long-term Preservation of Information and Memory for Geological Disposal of Radioactive Waste", NEA/RWM(2010)7/REV.

NEA (2009a), "Knowledge Consolidation and Transfer: The Vision and Expectations of the RWMC", NEA/RWM(2009)4/PROV, www.oecd-nea.org/rwm/docs/2009/rwm2009-4.pdf.

NEA (2009b), "Preserving Information and Memory Across Generations: Proposal for a Dedicated Initiative and Specific Project", NEA/RWM(2009)7, www.oecd-nea.org/rwm/docs/2009/rwm2009-7.pdf.

Posner, R.E. (1990), *Warnungen an die ferne Zukunft: Atommüll als Kommunikationsproblem*, Raben-Verlag, Munich.

Schröder, J. and C. Pescatore (2012), "Preservation of records, knowledge and memory across generations: An emerging multidisciplinary work area and an NEA project", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

Sebeok, T.A. (1984), "Communication Measures to Bridge Ten Millennia", BMI/ONWI--532, DE84014459, www.osti.gov/scitech/servlets/purl/6705990.

Setzman, E. (2014), "Preservation of information and communication with future generations", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

Trauth, K.M., S.C. Hora and R.V. Guzowski (1993), *Expert Judgement on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant*, SAND92-1382 l UC-721, prepared by Sandia National Laboratories for the US Department of Energy, Albuquerque, New Mexico and Livermore.

Weinberg, A. (1972), "Social institutions and nuclear energy", Science, Vol. 177(4043), pp. 27-34.

Wikander, O. (2015), "Don't push this button: Phoenician sarcophagi, "atomic priesthoods" and nuclear waste", Vetenskapssocieteten i Lund. Årsbok 2015, Rahm, H. Lund, Vetenskapssocieteten, Lund.

Chapter 2. **RK&M preservation: Fundamentals**

The RK&M initiative addressed the "why", "what", "when", "who" and "how" of RK&M preservation across generations. The first position of the "why" question in this list ("for which reasons and purposes do we need and want to preserve RK&M about radioactive waste across generations?") is crucial. It proved to be one of the most difficult, but perhaps also the most crucial question, since all the other questions, at least partly, depend on it.

There are three fundamental rationales for the preservation of RK&M:

- its connection to safety;
- protecting humans and the environment;
- supporting informed decision making.

2.1. **RK&M preservation and its connection to safety**

The repository: From "seclusion and oblivion" to a societally embedded facility

As explained previously (see Section 1.2), a historical review of RK&M related literature suggests a change in the rationale for RK&M preservation across generations. In many countries, traditional approaches were notably based on the premise that safety was best assured by keeping disposal facilities apart and isolated from society. The underlying assumption was that safety is best provided by keeping disposal facilities "under the radar" and by welcoming oblivion to take hold after closure. Efforts would be dedicated to keep people away from the site (e.g. by means of land use restrictions enforced by fences and surveillance for the shorter term and warning markers for the longer term). RK&M preservation across generations was not a priority and conceived approaches were predominantly prescriptive with regard to their message ("stay away") and static with regard to their implementation (archives and markers).

In recent years, more thought has also been dedicated to more dynamic mechanisms, such as continued monitoring, conditional reuse of sites and active participation by local communities in decision making. This trend for greater follow-up, flexibility and participation implies that disposal facilities would be part of the fabric of society, rather than operated in isolation from it (Pescatore and Mays in NEA, 2012: p. 98; NEA, 2015a). Moreover, waste management researchers are coming to terms with the fact that, independent of the technical durability, the societal durability of a once agreed disposal approach may not last forever (Schröder et al., 2016). More present-day thought is that rather than attempting to dictate or manipulate the emotions of future generations, RK&M structures and messages ought to try to inform those generations (A. Van Luik in NEA, 2012: pp. 88-89). Overall, there seems to be an evolution towards more openness regarding the future in long-term radioactive waste management (RWM) thinking and its accompanying RK&M strategies. Future generations are no longer solely conceived of as potential inadvertent intruders. There is openness towards the idea that accessing the repository may also be desirable for future generations, for whatever reason (see also Hotzel and Wisbey, 2016).[20]

20. As a participant to one of the RK&M initiative's workshops put it: "The notion that we know best and can and should dictate what people in hundreds of years' time should do, is ludicrous" (E. Van Hove in NEA, 2012, item 29, pp. 108-110).

It has been generally agreed that RK&M preservation is a fundamental aspect in establishing and running any long-term project that involves risks. In the context of RWM, RK&M preservation aims at keeping track of disposal projects across time by supporting an informed and alert attitude towards the required levels of safety, security and societal accordance, not only by the implementing agency and the authorities, but also by society at large and local communities in particular. As such, RK&M preservation concurrently performs a communication and an evaluation function. These functions do not change over time and are valid for the present as well as the future for both the operational and the post-operational phases of disposal facilities.

Introducing the concept of oversight

The general reasoning towards more societally embedded repositories and RK&M preservation has recently also been confirmed by the International Commission on Radiological Protection (ICRP), the most prominent international, non-governmental organisation with regard to recommendations and guidance on radiation protection. Together with the NEA, it introduced the notion of "oversight" as a new reference concept for reconciling geological disposal of radioactive waste with the fundamental principles of radiological protection (NEA/ICRP, 2013; ICRP, 2013; see also S. Hotzel in NEA, 2015b: pp. 65-70). It aims to elaborate the optimisation principle ("all exposures shall be kept as low as reasonably achievable" [ICRP, 1977]) over time (see also Section 3.4 on intra- and intergenerational ethics).

"Oversight is a general term for 'watchful care' and refers to society 'keeping an eye' on the technical system and the actual implementation of plans and decisions" (ICRP, 2013: p. 20). This description remains rather minimalistic, but it is agreed that oversight is always by people, complements the intrinsic or built-in controls that are carried out by the technical system itself and that one might expect that society will maintain forms of oversight as long as possible (ICRP, 2013: p. 35; see also S. Hotzel in NEA, 2015b: pp. 65-70; and Section 4.2 on time frames, where the difference between "direct" and "indirect oversight" is explained).

The notion of "oversight" is not in contrast with one of the main rationales for final, "passive" disposal (as opposed to prolonged, "active" storage), namely to limit the burden on future generations. While the burden may indeed be considered limited due to the fact that final disposal facilities offer radiation protection without requiring active maintenance, it nevertheless is clear that future generations will live with the consequences of our present activities and the radioactive waste we produce. Moreover, "the 'contain and concentrate' strategy makes it possible, in principle, for the waste to be re-accessed either voluntarily or involuntarily at some time in the future" (ICRP, 2013: p. 31). In this sense, the concept of oversight – and the RK&M preservation it requires – is understood as aligned with and in support of passively safe, long-term radioactive waste disposal (NEA, 2014).

This also is the opinion of the ICRP: "The obligations of the present generation towards the future generation are complex, involving, for instance, not only issues of safety and protection, but also transfer of knowledge and resources. Due to the technical and scientific uncertainties, and the evolution of society in the long term, it is generally acknowledged that the present generation is not able to ensure that societal action will be taken in the future, but needs to provide the means for future generations to cope with these issues" (ICRP, 2013: p. 29). RK&M preservation is fundamental to oversight (see also Section 5.8 on oversight provisions). The ICRP elaborates two fundamental rationales in this regard (which are elaborated in the following sections): "Measures to preserve the memory of a facility might help to reduce the probability of inadvertent human intrusion, and may assist the justification and planning of any deliberate intrusion should this be required in the future" (ICRP, 2013: p. 35).

2.2. Protecting humans and the environment

As will be explained in this section, the ethical principle of protecting humans and the environment entails – with respect to RK&M preservation – the following fundamental objective and task:

- objective: preventing inadvertent intrusion by future generations;
- task: preserving awareness of the repository.

According to Buchanan, "the most promising approach towards building a moral foundation for intergenerational obligations is based on the simple concept of avoiding harm to other living beings" (Buchanan, 2011). Radioactive waste disposal facilities aim to fulfil this obligation by isolating and containing radioactivity over time in a way that does not require human intervention. However, this long-term protection depends on the prevention of inappropriate action that would disturb the protective functions of the repository. This means that one needs to ensure that human actions do not disrupt the protection properties of the repository either by intrusion into the disposal cells or by disruption of the local environment/ host rock (Dumont et al., 2017).

Inadvertent, disruptive intrusions can take place due to ignorance or misinformation.[21] Disposing the waste at depth in an – according to our norms – uninteresting geological environment may aid to avoid inadvertent human intrusion (ICRP, 2013: pp. 43-44). However, as geological disposal itself shows, future investigations, such as deep drilling, can be carried out in bedrock consisting of common rocks without natural resources. Furthermore, in line with man's curious nature, "the more it is hidden, the larger is the temptation to get to it" can serve as a rule of thumb. Trusting and supporting oblivion does not help in this regard. Firstly, because one simply cannot impose oblivion or trust that future generations will "remember to forget". Secondly, because supporting oblivion contradicts the ethical principle of supporting informed decision making over time (see Section 2.3). Thirdly, because a strategy of forgetting the whereabouts of a radioactive material is in conflict with fundamental radiological protection principles and, in the case of fissile material, safeguards (see Section 5.10).

As a minimum, the task of RK&M preservation is thus to maintain awareness of the existence, location and risk of the repository. In line with the ethical principle of protecting humans and the environment, RK&M preservation is a concretisation of the optimisation principle in this regard. The RK&M initiative encourages awareness to be realised by means that encourage people to be alert and to look for further information (i.e. as part of a systemic strategy, see Chapters 5 and 6). RK&M mechanisms that are intended simply to scare or patronise people are not recommended (see also Section 4.4 on contents and Section 5.4 on markers).

2.3. Supporting informed decision making

The second fundamental objective of RK&M preservation, complementary to the first, is to provide future generations with as much relevant information as possible that might help them to make informed decisions about intentional actions and assess the consequences. This requires more than sheer awareness and also involves transmitting knowledge and memory related to the repository and its content (Dumont et al., 2017).

The second set of RK&M fundamental objectives and tasks is as follows:

- objective: enabling future generations to make informed decisions about the repository;
- task: preserving knowledge and memory of the repository (or the possibility to regain it).

21. For an analysis pointing out that there are various, qualitatively different future human intrusion scenarios, ranging in between the two poles of "no awareness at all" and "full knowledge and memory", see Hotzel and Wisbey, 2016.

The underlying ethical principle can be coined as "supporting informed decision making". The aim should be informing future generations in an attitude of openness to allow them to use information to their own interest, benefit and skills. It is acknowledged that these can change rapidly over time and that it is speculative to define what future generations want or need to know with respect to a repository (see also NEA, 2012: p. 31). Potential needs of future generations are not predictable, but can at most be approximated based on potential questions, needs and skills of today's generations (see also Section 4.4 on contents). The general idea remains that the availability of information about the repository will a) aid future deliberations about which decisions and actions may be desirable, and b) help to prepare the implementation of such decisions and actions. On the contrary, if the relevant information is no longer available, unnecessary exposures and costs may be incurred (see also Section 3.2 on RK&M loss). This might make the decision practically impossible to implement in the end and would decrease the resources available for other decisions. In both cases, this would reduce the scope of decisions that may be made. Providing support for a possible decision of intervention therefore corresponds to respect for freedom of choice of future generations by concretising the ethical principle of preserving conditions for informed decision making (see also Dumont et al., 2017). This principle does not imply that future generations have to undertake action, but it supports their capabilities to make this decision and the potential action involved in an informed manner.[22]

Supporting informed decision making over time involves not only the preservation of information in the form of records, but also of knowledge (defined as the result of a learning process, providing insights and skills) and memory (defined as the awareness of events, people, places and levels of knowledge in the past). Combined, the aim is to help future generations reconstruct and evaluate historical considerations and actions and, if desired, to construct and implement new ones. The principle relates to the preservation of both "technical" (e.g. the waste inventory, the containment and isolation functions, the repository design, and the risks) and "social" information (e.g. where the waste came from, the ethical basis of the disposal strategy, and the decision-making procedure). Contextual information of the latter kind is aimed at allowing future generations to understand the repository in a more fundamental way than through its technical layout alone. Even if the repository is left as it is, it may be interesting for the future to know how our society dealt with the issue of RWM and which values and knowledge were involved. In a similar way, the memory of ancient mines or ancient industrial activities in general is now considered worthy of retention, as a part of our cultural heritage (Dumont et al., 2017) (see also Section 5.6 on the culture, education and art approach).

2.4. References

Buchanan, N. (2011), "What kind of environment do we owe future generations?", *Lewis & Clark Law Review*, Vol. 15/2, pp. 339-367, https://ssrn.com/abstract=2101807.

Dumont, J.-N. et al. (2017), "Analysis of the needs for long term memory and knowledge preservation relating to radioactive waste disposal facilities", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

Hotzel, S. and S. Wisbey (2016), "Markers and beyond: Categorizing human intrusion situations to be addressed in sub-surface marking concepts", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

ICRP (2013), *Radiological Protection in Geological Disposal of Long-Lived Solid Radioactive Waste*, ICRP Publication 122, Annals of the ICRP, Vol. 42/3, pp. 1-57.

ICRP (1977), *Recommendations of the ICRP*, ICRP Publication 26, Annals of the ICRP, Vol. 1/3, www.icrp.org/publication.asp?id=ICRP%20Publication%2026.

22. For more information on "the capabilities approach" in ethics, see e.g. the Stanford Encyclopaedia of Philosophy (https://plato.stanford.edu/entries/capability-approach).

NEA (2019), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Developing a Key Information File for a Radioactive Waste Repository*, OECD, Paris.

NEA (2015a), *Fostering a Durable Relationship between a Waste Management Facility and its Host Community: Adding Value through Design and Process – 2015 Edition*, OECD, Paris.

NEA (2015b), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate,* OECD, Paris, www.oecd-nea.org/rwm/pubs/2015/7259-constructing-memory-2015.pdf.

NEA (2014), "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 (RWMC)", www.oecd-nea.org/rwm/rkm/documents/flyer-A4-rkm-collective-statement-en-2014.pdf.

NEA (2012), "The Preservation of Records, Knowledge and Memory (RK&M) across Generations: Scoping the Issue: Workshop Proceedings", www.oecd-nea.org/rwm/docs/2012/rwm_r_2012_6.pdf.

NEA/ICRP (2013), "Radiological Protection and Geological Disposal: The Guiding Principles and Recommendations of the International Commission on Radiological Protection (ICRP)", www.oecd-nea.org/rwm/documents/icrp-rp-gd.pdf.

Schröder, J., N. Rossignol and M. Van Oudheusden (2016), "Safety in long term radioactive waste management: Insight and oversight", *Safety Science,* Vol. 85, pp. 258-265, www.sciencedirect.com/science/article/pii/S0925753516000382.

Chapter 3. **RK&M preservation: Challenges and opportunities**

The question of "How can we continue to remember and understand across generations where, why and how hazardous waste is disposed?" is set against the background of certain challenges related to long-term radioactive waste management (RWM). Records, knowledge and memory (RK&M) preservation offers opportunities to address these challenges, but it poses new challenges too. This chapter outlines some of the most prominent challenges and opportunities of RWM related RK&M preservation.

3.1. **Information life cycle management**

How can we communicate with future generations and will they understand our messages? In an ideal communication situation, the sender and the receiver share a similar lifeworld and are able to interact, ask questions and give feedback to each other. For the case of radioactive waste disposal and taking into account the extended time frames of RWM, this opportunity is missing. Moreover, much of the available information is specialised and technical, causing communication challenges even in the present. To tackle these challenges, it is useful to identify the various steps of the RK&M preservation process. Three life cycle sub-processes have been identified (Dumont et al., 2017).

1. "Memorisation", at the producer level, where the information to be preserved is identified, collected, organised and expressed (i.e. made explicit). Memorisation will be based on existing information, which will need to be adapted and elaborated (e.g. with contextual information) to serve various audiences today and in the future, and on new information produced throughout the duration of the disposal project.
2. "Preservation", at the curator level, where the potential durability of "information carriers" (media) is extended both in the technical (tangible) sense (e.g. transferred to permanent paper) and in the social (intangible) sense (e.g. taken up in education), where the preservation and transmission conditions are optimised (e.g. entrusted to archiving institutions or shared among international organisations), and where information may be restored (e.g. if information carriers are becoming degraded or stories have become incomplete) and adapted to varying needs, findings and possibilities over time. The phases of "memorisation" and "preservation" thus partly overlap.
3. "Access", at the receiver level, where the receiver has to be aware of the existence of the information, has to be able to find the relevant pieces of information, and has to interpret and understand them in a meaningful way that is not in conflict with the fundamental RK&M preservation objectives of protecting and informing future generations. Future readers/interpreters "may be confronted with information because it has been continuously preserved, but they may also have rediscovered it and then try to make it understandable. Both of these possible situations must be taken into account" (Wikander, 2015: p. 120).

The time gap and the potentially different lifeworlds of the producer and the receiver cannot be addressed directly, but a multidisciplinary and participatory approach can at least serve as an access "pilot test" in the present (see Section 4.6 on actors and Section 6.5 on the participatory process). This is where RK&M preservation starts. If the present society is unaware of RWM practices, this is also more likely to be the case for the future society. RK&M preservation is not just a question of handing down a message, but of keeping that message

interpretable, credible[23] and meaningful. Hence the importance of dedicating attention to all three of the life cycle sub-processes, since RK&M loss can take place at all levels, as the following section illustrates.

3.2. Causes and consequences of RK&M loss

RK&M loss is real and already happening today, and not without consequences. Projects of any nature are vulnerable to risks of RK&M loss. RWM forms no exception in this regard and the long-term hazardous nature of the waste highlights the relevance of RK&M preservation in this field. To summarise, the point of departure of the RK&M initiative is that if we do not make efforts to substantiate and transfer RK&M, it will without doubt get (partly) lost, forgotten, or become inadequate for future understanding and decision making. Several case studies demonstrate this finding, as well as the fact that RK&M reconstruction is challenging from a practical, economic and safety point of view.

Insights on RK&M loss from both inside and outside the nuclear field were developed within the RK&M initiative. Two dedicated surveys were sent out to RK&M initiative members and beyond (the 2011 Survey on Examples of Memory Loss and the 2012 Survey on Costs Associated with Loss of RK&M in Decommissioning). A dedicated study was published to gain insights from RK&M loss in the area of conventional waste disposal (NEA, 2014). Specialists were invited to project meetings and workshops to present their experience on RK&M loss related to contaminated sites, cultural heritage, knowledge in general, and digital archiving. The examples focused notably on more or less recent cases, since these provide the most hands-on information, both with regard to the reasons and the consequences of RK&M loss.

Lessons from RK&M loss in the nuclear field

The 2011 Survey on Examples of Memory Loss revealed examples within the field of RWM (see S. Tunbrant in NEA, 2012: pp. 47-54). In Hungary for instance, the prolongation of an operational licence of the radioactive waste processing and storage facility required the reconstruction of the facilities and a renewed safety assessment in line with evolved state-of-the-art safety requirements. Very soon it became apparent that some information originating from earlier investigation programmes was not fit for use because of the lack of metadata, which would allow its reliability and quality to be assessed. People were unable to determine the original dataset, which data was used in the assessments and how the data was processed. This led to the necessity to redo some former sampling, measurements and data processing. The main lessons learnt are that safety is a dynamic concept and that new generations require good insight to previous approaches to be able to rely on and work with what has been done in the past. Information reconstruction is not always possible and is always costly.

In the United States, the Hanford site was established in 1943 as part of the Manhattan Project on the Columbia River, Washington. During 1945-1975, radioactive waste was buried away from the facilities. It was disposed at a place that, at the time, was considered to be “far away”, to prevent unintended intrusion. It was not marked to avoid drawing attention to its existence below its well-revegetated surface. However, the waste was discovered when excavating for other purposes. This is a case where radioactive waste itself got “lost” and regretfully, it is not the only instance worldwide where this has happened. The records were not totally lost, but were inadequate. The main lesson learnt here is that places once considered to be “far away” may become exploited when communities and industries evolve and grow. Hiding and trying to forget is not a good way to prevent inadvertent intrusion. Moreover, while RK&M preservation may seem irrelevant at one time, it may become useful or needed at later times.

23. Credible or “believable” is not per se the same as “believed” but refers to messages for instance not being a priori disregarded as outdated superstition, or incorrectly assessed with regard to its genre (scientifically based texts being read as prose, for instance) (Wikander, 2015).

In 2012 the RK&M initiative distributed a questionnaire to members of the NEA Working Party on Decommissioning and Dismantling and the NEA Co-operative Programme on Decommissioning related to consequences and costs associated with the loss of RK&M in decommissioning (see I. Rehak in NEA, 2013: pp. 101-102). It received 11 answers; all responses provided examples on records loss (e.g. lack of "as built" drawings, drawings comprising all up-to-date changes in systems and structures having been made during operation); a lack of information on material and radiological inventories of buildings, components, and radiological surveys; and a lack of information on operational history (including events) that may result in discovering an unexpected contamination. Five examples of knowledge loss were shared (e.g. difficulty with interpreting old records and lack of knowledge on how to retrieve archived information) and nine examples of memory loss were given (e.g. related to the retirement of operational staff and the lack of information in operational logs and other documentation).

RK&M loss occurred due to both physical and social reasons, such as not planning for future information needs, not updating information and information being scattered. All examples incurred negative consequences and costs, some marginal, but others significant. An illustration was mentioned in which over 25% of the duration of the total project had to be devoted to reconstructing a minimal amount of critical information to analyse the possible decommissioning and dismantling (D&D) strategies. New surveys of the contamination of the facility and dose rate surveys were necessary, which led to additional unnecessary exposure of the D&D personnel, thus breaching the principle of minimisation of radiation doses (J-G. Nokhamzon in NEA, 2013: p. 103). Overall, it was learnt that lack of RK&M can present the involved parties with considerable safety problems and can have a significant impact on project schedules and costs.

Lessons from RK&M loss outside the nuclear field

An exploratory investigation on RK&M loss was conducted based on 21 examples of landfills and contaminated sites in Switzerland, Germany and the United States (NEA, 2014; see also M. Buser in NEA, 2013: pp. 37-44). The examples were all drawn from non-nuclear industrial and military processes operated by a range of landowners including national government, local authorities, private companies and individuals. Each of them had a history in which the original waste disposal practice was forgotten or details had been lost, resulting in uncontrolled environmental contamination and costly clean-up. Combined with the analysis of the 2011 Survey on Examples of Memory Loss (S. Tunbrant in NEA, 2012: pp. 19 and 47-54), the following reasons for RK&M loss were identified as most relevant:

- no/poor records (e.g. with insufficient data to inform retrieval or remediation actions), lack of copies of sets of records or no/poor archives;
- no/insufficient update of information (e.g. maps, plans);
- no/insufficient budgets to fulfil RK&M preservation duties and economic discontinuities (e.g. bankruptcy);
- personnel changes (e.g. retirement, change of job);
- illegal activities (the deliberate destruction of records and knowledge) whether for avoiding legal prosecution, economic gain, political interests or shame about past conduct[24]);
- societal discontinuities (e.g. war, shift of national boundaries);
- technical failures or environmental degradation of records.

24. The main investigator of the study (NEA, 2014c), M. Buser, in fact mentioned difficulties in retracing reasons for RK&M loss due to the sensitivity of the issue in multiple case studies.

Interestingly, technical or environmental factors seem to have the smallest impact of all analysed factors (M. Buser in NEA, 2013: p. 44). With the exception of the two factors mentioned under the last bullet above, the source of loss is directly related in one way or another with human aspects notably related to:

- deficient regulatory guidelines and their enforcement;
- lack of funding, lack of organisational/institutional continuity;
- carelessness (disinterest, negligence, ignorance or incompetence) or wilfully forgetting.

With regard to the last factor above, R. Moxham, author of historical books, also highlighted how, over the longer term, RK&M disappear when they are linked to parts of history that are not deemed particularly positive (R. Moxham in NEA, 2015: pp. 75-87). Regarding the shorter term, another study on RK&M loss related to contaminated sites in Switzerland revealed power games between state officials, representatives of the industry, technical experts, politics and the general population in all of the case studies. Information may be out there, but not in the right place or not with the right people. It was thus pointed out that differences in institutional interests, rivalry, politics and power imbalances can play a major role (Ch. Sieber in NEA, 2012: pp. 20 and 54-57).

Overall, short-term thinking was a key factor to RK&M loss. It may take generations before the effects of inappropriate practices come to the attention of policy makers and regulators, and only when RK&M becomes acutely needed. The fact that environmental consequences are often not acute and that authorities tend to aim to best serve the interests of society during their own time in office are two ingredients of a common recipe for RK&M loss. The same may apply for industry where it is common to only fulfil the minimum requirements of the law. RK&M loss often only becomes an issue in the context of later clean-up activities either out of a wish for developing new economic activities at waste sites or due to shifts in the perception of ecological values (S. Tunbrant in NEA, 2012: pp. 19 and 47-54; see also T. Schneider in NEA, 2012: pp. 104-105). This also tells us that perceptions of RWM, concepts for final disposal, environmental valuations and understandings of safety change over the course of time.

Moreover, people with different disciplinary backgrounds may look at these issues differently, thus calling for a multidisciplinary approach in designing both waste management and RK&M preservation strategies (see also Section 4.6 on actors). Also, within organisations it is important to establish good communication paths between different organisational units. There are plentiful examples where data and information are archived/preserved in one part of an organisation (authority, company, municipality, etc.) and not available to another part of the same organisation that needs them (S. Tunbrant in NEA, 2012: p. 19).

It is important to outline that for many of the examples studied, there never was a dedicated reflection on or explicit intention to keep RK&M at the time. In such a setting, RK&M loss was found to be a very fast process (decades) that notably has to do with a general lack of awareness of the importance of RK&M preservation issues and the dedicated effort it requires. Even if the willingness to preserve RK&M is present, the reality remains that in the longer term, materials degrade, meanings and values change according to culture and context, and RK&M can be manipulated or misused (e.g. as a way of holding power over others). The more general lesson learnt here is that a regulatory framework, an organisational culture, a broader societal scrutiny, and an interest in the matter prove indispensable boundary conditions for RK&M preservation.

On the simplest level of analysis, there are two different forms of RK&M loss. There is epistemic loss when the information is physically available, but not found or understood, and there is physical loss of information when its carriers are no longer available. Invited expert J. Springer of the UNESCO's Memory of the World Programme explained that in the field of documentary heritage "whether it is recorded on clay, stone tablets or papyrus scrolls; in manuscripts or books; in the form of photographs, film or sound recordings; or accessible through modern media such as blogs and the internet, documents are fleeting and face the risk of disappearing without a trace. The causes are many: war and social upheaval, natural catastrophes (water, fire, earthquakes, etc.), chemical deterioration, technological obsolescence, wilful destruction, neglect and lack of funding. These have all caused the loss of significant documents around the world" (J. Springer in NEA, 2013: p. 87).

The enormous advances in both the technical possibilities and societal availability of information and communication technology (ICT) may work for, but also against RK&M preservation across generations. "The output of the present century alone is probably greater than the total output of all previous centuries put together; and ironically and tragically, it is being lost faster than ever before".[25] The culling of information is necessary to avoid situations of "keep everything, find nothing", but information selection needs to be carried out with the greatest care, a topic that was also studied within the RK&M initiative (see Section 5.2 on the dedicated record sets and summary files approach, and NEA, 2019 and NEA, forthcoming-b). Similar complexities exist with regard to digitisation. "One of the major global misunderstandings is the assumption that digitisation means preservation, when in fact it is only a small part of the process. Preservation of digital information requires a permanent logistic and financial commitment in order to remain accessible" (J. Springer in NEA, 2013: pp. 87-88; see also Section 4.3 on multiple media).[26]

Dedicating proper attention to media is definitely important. Nevertheless, preserving records or information carriers more broadly is not sufficient. It is not because they exist that they are also remembered, used, understood or believed. Studying RK&M loss confirmed the inter-connectedness of records, knowledge and memory. It is not only about keeping information, but about preserving selected data and information that have been committed to a medium and accompanied by the appropriate context and structure for later uses (records). Moreover, records in themselves have limited meaning without the ability to understand and utilise the data and information they carry (knowledge) (see also J. Day in NEA, 2012: p. 73). In order for this combination of records and knowledge to be transferred across generations, there needs to be awareness of their existence and of the reason for their existence, which is aided by a broader awareness of events, people, places and levels of knowledge in the past (memory).

3.3. RK&M preservation in a regulatory context

The RK&M initiative members investigated if and how RK&M preservation across generations is currently regulated. Preliminary insights gained through exploratory surveys distributed among implementing agencies and regulators[27] indicated that this too was a domain with both challenges and opportunities. Responses revealed firstly, some need for RK&M preservation to be accompanied by regulatory guidance; secondly, that this is insufficiently the case at present in most countries; and thirdly, that developing such guidance faces some challenges, for instance with regard to the level of required detail, the actions to be prescribed, and the identification of the actors that should carry out and control these actions over time.

The three initial findings mentioned above confirmed the relevance of further studying and developing regulations in the framework of RK&M preservation. Firstly, the connection of RK&M preservation to safety (see Section 2.1). Secondly, the identification of crucial factors for RK&M loss (NEA, 2014; see also Section 3.2), such as the lack of regulatory guidelines and the lack of enforcement where guidelines exist. Thirdly, during the time of the RK&M initiative, RK&M preservation was taken up in international regulations and guidelines for long-term RWM, which would have to become transposed into national regulations and guidelines by member states. The 2011 European Directive on the responsible and safe management of

25. Dato' Habibah Zon, Director-General of the National Archives of Malaysia, cited by Marinos Ioannides, conference opening of the Constructing Memory Conference, 15 September, Verdun, France (www.oecd-nea.org/rwm/rkm/constructingmemory).

26. See also Palm, J. (2005), *The Digital Black Hole*. Available online from www.tape-online.net/docs/Palm_Black_Hole.pdf.

27. 2010 Survey on Status and Needs, 2011 Survey on Responsibilities (see S. Wisbey in NEA, 2012: pp. 17-19), 2012 Survey with Questions of Regulatory Significance (focused on the national implementation of the European Waste Directive, see C. Mays, C. Pescatore and H. Gordon-Smith in NEA, 2013: pp. 21-25) and 2012 Survey on RK&M and the Safety Case (distributed to the NEA IGSC, see G. Kwong in NEA, 2013: pp. 25-26).

spent fuel and radioactive waste[28] states that the contents of national programmes should include "concepts or plans for the post-closure period of a disposal facility's lifetime, including the period during which appropriate controls are retained and the means to be employed to preserve knowledge of that facility in the longer term" [29] (EU, 2011: article 12(e); see also C. Mays, C. Pescatore and H. Gordon-Smith in NEA, 2013: pp. 21-24). Also, as mentioned earlier (Section 2.1 related to the concept of oversight), in 2013 the ICRP brought the concept of "oversight" to the fore as an important contributor to the optimisation of radiological protection in the context of geological disposal, thus recommending to organise oversight and sustain it among others by RK&M preservation (ICRP, 2013; NEA/ICRP, 2013).

It needs to be noted that regulation relevant to RK&M preservation can come from multiple sources (not only from the nuclear field and regulator) and multiple levels (international, national, regional and local). Regulations that relate directly or indirectly to RK&M preservation may be found in the following areas:

- environmental protection and the right to be informed and participate in environmentally relevant activities;
- spatial planning (e.g. land title registers, restrictions and responsibilities, including use of geology, e.g. drilling and mining records);
- safety (nuclear and non-nuclear, e.g. related to construction permits and industrial safety) and security (nuclear and non-nuclear, e.g. safeguards and data protection);
- heritage preservation;
- archiving (cross-cutting all previous domains).

This broad range of regulatory sources was the first challenge encountered. It may cause divergence and lack of overview on the level of both content and responsibilities. On a systemic RK&M preservation level, it also provides opportunities for collaboration, learning and redundancy (see also Chapters 4 and 5).

National RK&M preservation regulation

To study and compare how national policy makers and regulators in the nuclear field currently formulate and put requirements in place to ensure that applicants address long-term RK&M preservation in their repository projects and what role this has in the stepwise licensing process, a "Regulatory Catalogue" was compiled (NEA, forthcoming-a). It collates all of the existing legislation, regulation and guidance [30] (hereafter referred to as "regulation"), which currently govern the preservation of RK&M for the final disposal of radioactive waste in 12 member countries.[31] Maintaining and updating the catalogue was an ongoing task throughout the duration of the RK&M initiative. Its content was "frozen" (i.e. no longer updated) in February 2018. RK&M regulation clearly is an evolving field, so the content of the catalogue needs to be understood as "a snapshot in time". The catalogue moreover needs to be understood as a factual collection of information to illustrate and compare, not a normative study.

28. The Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste. Available online from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:199:0048:0056:EN:PDF.
29. The term "knowledge" as employed in the directive appears to correspond to the term "memory" as defined in the RK&M glossary. The term "longer term" in the directive appears to correspond to "medium term" as defined in the RK&M glossary (see Annex 1).
30. *Legislation* is passed by a parliament and is general in nature (e.g. "the regulator has the authority to set dose limits"). *Regulation* is produced by the executive (i.e. the governmental department/agency) within the authority provided by the law and contains practical details (e.g. the dose limits itself). *Regulatory guidelines* contain additional information on how to meet regulation.
31. Belgium, Canada, Czech Republic, France, Germany, Hungary, Japan, Spain, Sweden, Switzerland, United Kingdom and United States.

Because of the differences in legal structures and regulatory frameworks among countries, some differences in RK&M preservation concepts were not unexpected. Nonetheless, the lack of similarity among both the terminology used and the actual requirements in the different countries is quite striking, to the point where it is difficult to discern trends or perform a thematic analysis of the existing RK&M preservation requirements. However, a few observations can still be made at a general level, including the following:

- All countries studied have some regulatory requirements for preservation of records. These requirements are often specific for records that are required in the "very short term" in support of licensing activities, but not specific about the reasons and means for preserving them in the longer term.
- No regulatory requirements on knowledge as defined by the RK&M glossary definition (i.e. the ability to understand and utilise records and information in general [see Annex 1: RK&M glossary]) can be traced in current regulations, which indicates that knowledge is a difficult notion to legislate for.
- In countries where preservation of memory of the existence and location of a repository is explicitly reflected in regulations, requirements may range from general (e.g. in Belgian and Hungarian law one finds the formulation of the EU waste Directive's requirement for national programmes to describe "the means to be employed to preserve knowledge of that facility in the longer term") to specific requirements for the establishment of protection zones (e.g. Switzerland and the United States) or concepts for marking the repository site (e.g. Switzerland and the United States).
- In all countries, the safety analysis must demonstrate that long-term safety criteria will be met even if RK&M are not preserved. In many countries regulatory requirements for archiving records can be read as an additional element of safety assurance. Institutional presence beyond the operational phase seems either implicitly or explicitly assumed.
- There is currently no overall trend to be seen in how to regulate the long-term preservation of RK&M for the final disposal of radioactive waste.

Cognisance of the importance of short-term awareness and action for RK&M preservation is already reflected in present guidance to a certain degree, for instance on record keeping and archiving (IAEA, 2006a; NWTRB, 2013). However, the analysis of the RK&M regulatory catalogue revealed that existing RWM related RK&M preservation regulation may lack precision and seems to struggle with providing guidance beyond archiving records in the immediate context of licensing requirements. The focus is on compliance, not so much on accessibility, and even less on understandability over time. From this perspective, it is essential to supplement the existing regulations of those countries that utilise nuclear energy in order to support RK&M preservation for the future. A key challenge in this regard is in giving guidance on how, from a regulatory point of view, to connect records with knowledge and memory, and linking the operational with the post-closure phase (J. Schröder in NEA, 2015: pp. 44-45).

While regulation cannot be seen as the only solution to the issue at stake, especially if it stops at the simple requirement to "keep any relevant records" (see also Section 5.2 on dedicated record sets and summary files), it is a crucial component of any long-term RK&M preservation strategy. It is still unclear to what extent policy makers and authorities in the nuclear field are aware of the finding that a regulatory framework, which would support an organisational culture and broader societal scrutiny and interest in the matter, is an indispensable boundary condition for RK&M preservation. The RK&M initiative aims to rouse this awareness and to offer suggestions on how to act upon it (see Chapters 5 and 6).

Planning responsibilities over time

Despite silent recognition of the fact that present institutions (such as the implementing agency and the regulator) will not continue to exist in perpetuity, the issue of who will be responsible for the repository in the longer term is hardly covered by current regulation. Regulations appear to be primarily concerned with the period during which existing institutional frameworks are expected to continue (i.e. up to the time of closure). When the transfer of responsibilities is

mentioned in international documents, it is always done in a very general manner. The IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management for instance, generically stipulates that during the post-closure period of "active institutional control" – which is not further defined nor delineated in time – it is the state that is responsible for making sure that monitoring, land use restrictions and record keeping continue, and for detecting and intervening in case of non-compliant performance (IAEA, 2006b: art. 17). The means and actors by which these oversight functions should be performed over time are not further elaborated. Also, the ICRP writes: "In the post-operational period, after the end of active regulatory oversight, maintaining indirect oversight and memory of the facility should become a societal responsibility, possibly discharged through national or local government" (ICRP, 2013: p. 35). The lack or vagueness of regulation in this regard is problematic, since the risk of losing RK&M can be particularly high when projects end and responsibilities are transferred to other bodies (NEA, 2014).

Regulation is a dynamic and ongoing process. On the one hand this implies that – with a view to the future closing licence of a disposal facility, which will likely include a lot of details related to RK&M preservation in general and the planning of responsibilities in particular – premature regulation could be unhelpful. On the other hand, from the very point of view of RK&M preservation and the planning of responsibilities, a proactive attitude is of key importance. Although the term is used rather often, at present it remains unclear what "licence termination" of a disposal facility implies in many countries. If there is no vision related to who will take up RK&M preservation and other responsibilities today when interest is high and financial means available, why should we expect future generations to draw one up? Also, would the coming generations not benefit from previous information, discussions and proposals?

Moreover, one should not expect actors that were never involved in RWM to suddenly take over and feel responsible. Having a plan for if, how and when responsibilities (and information to fulfil those responsibilities) would be transferred would also enhance the general confidence that the waste management system is run in a responsible manner, and it would reduce uncertainties about future evolutions, in particular for the host communities. There exists some experience with the transfer of responsibilities after the closure of nuclear sites related to former uranium mines in Spain (site around the Andújar mill), Germany (sites operated by the former Wismut company) and Canada (sites in the provinces of Saskatchewan and Ontario). In the United States, the Office of Legacy Management was specifically established to ensure the management of nuclear legacy sites after regulatory closure. Drawing on the experiences at these sites and of these agencies, even if their existence is still limited in time and RK&M preservation may not be their explicit core task, would be worthwhile (see also Section 5.8 on oversight provisions).

In summary, since some of the issues related to preservation of RK&M across generations may transcend the typical boundaries of the responsibility of present-day regulators, the roles of other actors (local, national and international) today and over time, merit further investigation. The same goes for accompanying issues such as the implications of sharing of responsibility among various institutions and the modalities of responsibility transfers (e.g. at the time of closure). This recommendation is treated further in Chapter 4 (notably Sections 4.6 on actors and 4.7 on locations) and Chapter 5 (notably the approaches described in Sections 5.8–5.10).

International soft law

Apart from regulation in the strict sense, there also exists a broad array of international "soft law" (such as conventions, declarations, codes of conduct) that can be interpreted as stimulating (but not enforcing) RK&M preservation. We notably refer here to internationally agreed principles often referred to in the context of RWM, such as sustainable development[32] the

32. "Meeting the needs of the present without compromising the ability of future generations to meet their own needs". Report of the World Commission on Environment and Development: Our Common Future ('Brundtland Report'), 1987.

polluter pays principle (PPP),[33] the precautionary principle[34] and the right to access to environmental information.[35] These principles are intergenerational in scope and can be interpreted as generally pointing out that we are ethically compelled to do the best we can to reduce the transmitted risks, to enable awareness about residual risks and to support related informed decision making over time (see also NEA, 2015: pp. 29-30).

The international principles just mentioned are, however, not without controversy. Due to their interpretative flexibility, they can be used by both proponents and opponents of certain RWM strategies. Nevertheless, they offer guiding reflective frameworks for RK&M preservation. The notion of "sustainable development" encourages us to reflect upon what it means to balance the needs of current and future generations, the PPP on what it means to maintain the environment in an "acceptable state" (see also Section 3.4 on costs and funding). The precautionary principle can be interpreted in two potentially conflicting ways. In one sense, it can be read as: when potential adverse effects are not fully understood, action should not proceed (emphasising the principle of no harm). In another sense, it can be read as: lack of scientific evidence does not preclude action if damage would otherwise be serious and irreversible (emphasising the principle of no regret). For the case of radioactive waste disposal, RK&M preservation may be interpreted as a bridge between both interpretations of the precautionary principle. RK&M preservation can be said to be most directly hinged upon the right to access environmental information, both in the present and across generations.

Regulation: a necessary condition for RK&M preservation

To summarise this overall section on the challenges and opportunities of a regulatory context for RK&M preservation, the RK&M initiative acknowledges regulating RK&M preservation is indeed a challenge. It is a dynamic, context-dependent issue that does not easily lend itself to being translated into tight rules. The lack of similarity among both the terminology used and the actual requirements in the different countries, to the point that it is difficult to discern trends or perform a thematic analysis of the existing requirements, is telling in this regard. The success of RK&M preservation strategy depends on whether or not it establishes the relevance and responsibility in the minds and attitudes of waste producers, regulators, implementing agencies, other stakeholders[36] and the general public today, and whether that need and responsibility is understood and passed on to the next generation (NEA, 2013: p. 108). Yet minds and attitudes are difficult to regulate.

Nevertheless, the regulatory context also offers opportunities for RK&M preservation. In fact, proactive regulatory guidance on RK&M preservation is of key importance, due to its connection to safety and because RK&M preservation does not "happen by itself" while RK&M loss does. Regulation should equip RWM actors with concepts and guidelines that are clear

33. "Under the 1972 and 1974 OECD Recommendations, the Polluter-Pays Principle means that the polluter should bear the "costs of pollution prevention and control measures", the latter being "measures decided by public authorities to ensure that the environment is in an acceptable state". In other words the polluter has to bear the cost of steps that he is legally bound to take to protect the environment, such as measures to reduce the pollutant emissions at source and measures to avoid pollution by collective treatment of effluent from a polluting installation and other sources of pollution" (OECD, 1992).

34. "If an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus, the burden of proof that it is not harmful falls on those taking an action that may or may not be a risk". Principle 15 of The Rio Declaration on Environment and Development, produced at the 1992 United Nations Conference on Environment and Development (UNCED).

35. The United Nations Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters ("Aarhus Convention"), 1998. The Aarhus Convention is legally binding for all the States who ratified it, but the way it is concretised varies greatly among countries and domains and the addressees are public authorities, not the private sector.

36. The RK&M initiative adapted the definition of "Stakeholder" formulated the FSC (www.oecd-nea.org/rwm/docs/2013/6988-fsc-glossary.pdf) as follows: any actor – institution, group or individual – with an interest, a concern, or a role to play in the radioactive waste management related RK&M preservation process.

enough, not only to initiate action and planning today and over time, but also to enable compliance review and enforcement mechanisms today and over time. The issue of RK&M preservation is thus also connected to the issue of planning responsibilities over time. While national nuclear regulators are key actors in this field, other regulatory fields are also involved, and international attuning is recommended.

Overall, a variety of interconnected RK&M approaches and mechanisms with different characteristics is recommended, regulation being one of them. As such, regulation alone is not a sufficient condition for developing and implementing a successful RK&M preservation strategy, but it is a necessary one.

3.4. Intra- and intergenerational ethics in terms of costs and funding

Challenges and opportunities also arise in relation to the costs and the funding of RK&M preservation across generations. The discussion relates to the PPP, but also to the radiation protection optimisation principle (see also Section 2.1 on oversight). What does "keeping radiation exposures as low as reasonably achievable, taking into account economic and social factors" (ICRP, 1977) mean in practice, not only today, but also over time? Controversy exists related to a risk of economic disproportionality, one side warning for "too little", the other for "too much". Criticisms range from allegations that the economic clause results in authorities "putting a price on a life", to that it results in the investment of "excessive funds to reduce trivial risks" (D. Oughton in SSI, 2000: p. 31).

Similar lines of discussion took place within the RK&M initiative (see NEA, 2013: session 9, pp. 101-108), extending the issue into the future. On the one hand, it was pointed out that, compared to the total costs of a disposal repository, the financial costs of RK&M preservation can be relatively low, while the respective benefits can be high (see also Section 3.2, outlining that the loss of RK&M is not unlikely to incur financial costs, both in the present and in the future). On the other hand, the question was raised whether it is justified to spend certain costs today to attempt to prevent uncertain costs in the future.

The latter question was notably raised by American RK&M initiative members (see Van Luik et al., 2016). In their 1993 recommendations, the Marker Panel members (see Section 1.2) stated the following: "We obviously recommend that a very large investment be made in the overall framework of this system, in the marking of the entire site" (Trauth et al., 1993: p. F-49). In line with this recommendation, the respective RK&M preservation budget estimation (including records management and storage, awareness triggers, conceptual permanent marker design and testing schedules) for the WIPP Compliance Application presented to the US Environmental Protection Agency in 1997, was indeed high (see also R. Patterson et al. in NEA, 2013: pp. 104-105). This raised discussions on "distributive justice" (i.e. the fair distribution of economic resources, both within [intra-generational] and across [intergenerational] generations [one opinion can be found in Van Luik et al., 2016]).

The issue of "how much will it cost" is connected to the question of "how will it be funded". In this regard, a difference can be made between "mediated" and "non-mediated" RK&M preservation strategies (see Section 4.5 on transmission modes). For the latter, which aims at a communication strategy that does not require intermediaries, costs would be borne by the current generation by means of upfront investment. For the former, which aims at a communication strategy that relies on intermediary generations, costs would be spread among generations with the potential for the current generation to make investments that are hoped to deliver interests or income across time. Drafting a budget is easier for non-mediated than for mediated transmission. The cost of designing and creating a marker, for instance, can be estimated. The concept of a "percent for art" also offers inspiration in this regard. It refers to the placement of a fee, usually some percentage of the total cost, on large-scale development projects in order to fund the development and installation of public art (see also Section 5.6 on

the culture, education and art approach).[37] One proposal for the funding of mediated RK&M transmission is to create a dedicated RK&M fund (see also J-N. Dumont in NEA, 2013: pp. 105-108). For the low- and intermediate-level waste repository project in Belgium, a "Local Fund" was created, which is meant to last for the duration of the hazard and thus of the repository.[38] If possible, only the interest is to be used, in analogy with the Nobel fund (see also J-N. Dumont in NEA, 2013: pp. 106-107) and to be invested in local projects that benefit the community and keep the memory of the repository alive.

In summary, the existing discussion on the issue of costs and funding related to the PPP and the optimisation of radiation protection, is made even more complex in light of the long time frames involved in RWM and, from a cost-benefit point of view, the unprovable benefits of long-term RK&M preservation. The economic discussion about the optimisation principle even reached the Vatican. In 1983 the Pontifical Academy of Sciences drew the conclusion that "it is the responsibility of the protection authorities to seek society's acceptance of a level of radiation protection which is the highest possible without conflict with other legitimate needs and duties of society" (B. Lindell in SSI, 2000: p. 21).

What is certain is that RK&M preservation is often not part of the disposal budget at present. This may incur an underestimation of the overall cost of disposal programmes today and in the future. The RK&M initiative thus recommends dedicated participatory and creative thinking and action with regard to RK&M preservation financing, fund creation and investments. "The economic challenges for long-term RK&M preservation must be analysed and allowance made for them in future programmes" (NEA, 2011), including deliberations on intra- and intergenerational distributive justice.

3.5. **References**

Dumont, J.-N. et al. (2017), "Analysis of the needs for long term memory and knowledge preservation relating to radioactive waste disposal facilities", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

EU (2011), Council Directive 2011/70/EURATOM of 19 July 2011 "Establishing a Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste", *Official Journal of the European Union*, 2 August 2011 (L 199/48).

IAEA (2006a), *Data Requirements and Maintenance of Records for Spent Fuel Management: A Review*, AEA-TECDOC-1519, IAEA, Vienna.

IAEA (2006b), *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*, IAEA International Law Series No. 1., IAEA, Vienna.

ICRP (2013), *Radiological Protection in Geological Disposal of Long-Lived Solid Radioactive Waste*, ICRP Publication 122, Annals of the ICRP, Vol. 42/3, pp. 1-57.

ICRP (1977), *Recommendations of the ICRP*, ICRP Publication 26, Annals of the ICRP, Vol. 1/3, www.icrp.org/publication.asp?id=ICRP%20Publication%2026.

NEA (forthcoming-a), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Catalogue of Legislation, Regulation and Guidance Governing the Preservation of RK&M for Radioactive Waste Repositories*, OECD, Paris.

NEA (forthcoming-b), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Compiling a Set of Essential Records for a Radioactive Waste Repository*, OECD, Paris.

37. In Ireland for instance, one percent of the cost of all public works can be allocated to commissioning a work of art. The General National Guidelines can be found here: www.publicart.ie/fileadmin/user_upload/PDF_Folder/Public_Art_Per_Cent_for_Art.pdf.

38. See www.niras.be/meerwaarden-voor-de-regio (in Dutch) or www.ondraf.be/des-plus-values-pour-la-r%C3%A9gion (in French).

NEA (2019), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Developing a Key Information File for a Radioactive Waste Repository*, OECD, Paris.

NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate,* OECD, Paris, www.oecd-nea.org/rwm/pubs/2015/7259-constructing-memory-2015.pdf.

NEA (2014), "Preservation of Records, Knowledge and Memory across Generations: Loss of Information, Records, Knowledge and Memory in the Area of Conventional Waste Disposal", NEA/RWM/R(2014)3, www.oecd-nea.org/rwm/docs/2014/rwm-r2014-3.pdf.

NEA (2013), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding", www.oecd-nea.org/rwm/reports/2013/rwm-r2013-3.pdf.

NEA (2012), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue: Workshop proceedings", www.oecd-nea.org/rwm/docs/2012/rwm_r_2012_6.pdf.

NEA (2011), "Preservation of Records, Knowledge and Memory across generations: A Collective Statement of the NEA Radioactive Waste Management Committee (RWMC)", www.oecd-nea.org/rwm/rkm/documents/rkm-collective-statement-2011-en.pdf.

NEA/ICRP (2013), "Radiological Protection and Geological Disposal: The Guiding Principles and Recommendations of the International Commission on Radiological Protection (ICRP)", www.oecd-nea.org/rwm/documents/icrp-rp-gd.pdf.

NWTRB (2013), "Review of US Department of Energy Activities to Preserve Records Created by the Yucca Mountain Repository: A Report to Congress and the Secretary of Energy", US NWTRB, Washington.

OECD (1992), "The Polluter-Pays Principle: OECD Analyses and Recommendations", OCDE/GD(92)81, www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD(92)81&docLanguage=En.

SSI (2000), "Ethical Issues in Radiation Protection – An International Workshop", SSI, Stockholm.

Trauth, K.M., S.C. Hora and R.V. Guzowski (1993), *Expert Judgement on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant*, SAND92–1382 l UC–721, prepared by Sandia National Laboratories for the United States Department of Energy, Albuquerque, New Mexico and Livermore.

Wikander, O. (2015), "Don't push this button: Phoenician sarcophagi, "atomic priesthoods" and nuclear waste", *Vetenskapssocieteten i Lund. Årsbok 2015*, Rahm, H. Lund, Vetenskapssocieteten, Lund.

Van Luik, A., T. Klein and G. Sahd (2016), "Ethical Considerations for developing repository warning messages to the future", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

Chapter 4. Key characteristics of RK&M preservation approaches and mechanisms

4.1. Introducing the idea of a "systemic strategy" for RK&M preservation

While the previous chapters were notably aimed at developing a theoretically founded, broad-based understanding of the issue at stake (records, knowledge and memory [RK&M] preservation's historical evolutions, fundamental reasons, and challenges and opportunities), we now start to make the transition towards turning this understanding into more practical insights and recommendations. These are hinged upon the notion of what the RK&M initiative refers to as a "systemic RK&M preservation strategy". Summarised, this refers to the finding that there is no single approach or mechanism that would achieve, on its own, the preservation of RK&M over centuries and millennia. To state it bluntly, simply putting up a marker or dumping records in an archive will not do much. Rather, a systemic RK&M preservation strategy is needed that comprehends a variety of RK&M transmission approaches, with multiple mechanisms with different key characteristics, that are integrated with one another or that are complementary, act as indexes to each other, and provide for diversity and redundancy, with a view to maximising information accessibility, understandability and survivability over the various timescales considered.

While Chapter 5 describes the different RK&M preservation approaches identified by the RK&M initiative, linked to Annex 2.2 with a variety of mechanisms within each approach[39] (the "toolbox" or "building blocks" of a systemic RK&M preservation strategy), this chapter first explains their diversity in terms of various key characteristics (the "composition of the building blocks", pointing out and promoting diversity related to time frames, media, contents, transmission modes, actors and locations). Chapter 6 contains suggestions on how to combine the different approaches and mechanisms into a systemic RK&M preservation strategy (the "building instructions").

4.2. Multiple time frames

The RK&M initiative focused on RK&M preservation for the post-closure phase of radioactive waste disposal facilities. Two remarks already indicated earlier are important in this regard.

Firstly, we can only speculate about what future generations will make of our repositories. Natural scientists are used to thinking in terms of long-term scenarios to address potential developments of materials and geology when modelling the long-term safety of a repository. But such an approach cannot be applied to society. Since all references to societies in the distant future remain elusive, detailed forward modelling is impossible. "Nothing ages faster than the future" (C. Holtorf and A. Högberg in NEA, 2012: p. 85). Societal variety and discontinuities of the kind that are present around the world today can and should be taken into account when developing RK&M preservation strategies. However, the RK&M initiative recommends to refrain from science fiction and futurology, and to pragmatically presume a future society more or less like ours (even when knowing that it will undoubtedly look very different) (see also Section 4.4 on contents).

39. To illustrate the terminology of "approaches" and "mechanisms": within the overarching marker *approach*, one finds for instance the concrete *mechanisms* of surface markers and sub-surface markers.

The success of RK&M preservation thus cannot be judged by whether RK&M will last for one thousand or ten thousand years. This remains impossible to predict or demonstrate. The success can only be judged in an ongoing manner by assessing whether it establishes the relevance and responsibility in the minds and attitudes of waste producers, regulators, implementing agencies, other stakeholders and the general public today, and whether that need and responsibility is understood and passed on to the next generation (NEA, 2013a: p. 108). A second remark, connected to the first, is that while the focus is on preserving RK&M for the post-closure repository phase, the RK&M initiative emphasises that RK&M preservation starts today and needs to be acted upon in the decades leading up to repository closure. It highlights the importance of applying life cycle thinking in RK&M preservation by interconnecting the pre-operational, operational and post-operational phases of repository projects. From a pragmatic point of view, this highlights that the RK&M preservation processes are as important as its products. Furthermore, from a more ethical point of view, it recommends to see the long term as an extension of the responsibility we feel for the next generations (E. Van Hove in NEA, 2012: p. 33).

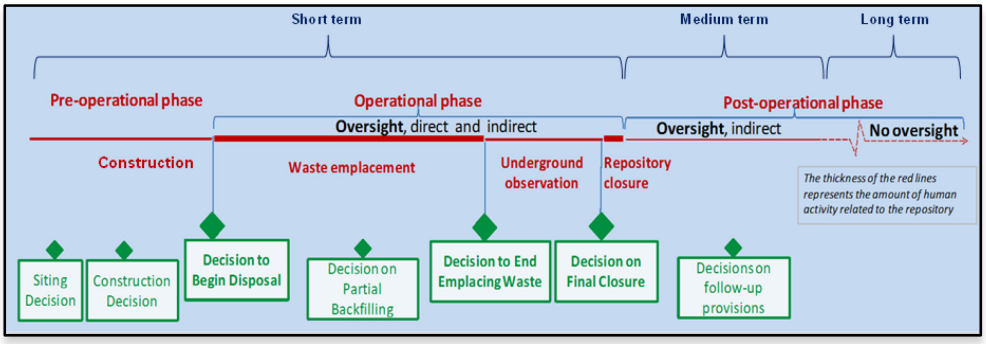
The focus of RK&M preservation is on the future, but concurrently on the practical present (What can we do today?). To explain this better, three time-related questions have been developed (see the respective section in the RK&M preservation mechanism description sheets in Annex 2.2), that relate to the three life cycle sub-processes of RK&M preservation elaborated earlier (memorisation/producer; preservation/curator; and access/receiver, see Section 3.1):

- When should the mechanism be developed (development timescale)?
- When should the mechanism be implemented (implementation timescale)?
- Which timescale(s) is the mechanism mainly aimed at (target timescale)?

Similar to the RK&M life cycle sub-processes, these timescales are interconnected as well. Staged structuring is theoretically and pragmatically instructive, but in practice phases of development (RK&M production) and implementation (RK&M application) overlap (approaches and mechanisms being continuously developed during their implementation). Moreover, extrapolating research results to real life conditions is never static (see also Schröder, 2015: p. 689), and thus RK&M preservation strategies that are contextually attuned and in line with "learning by doing", flexible and adaptable over time are recommended (see also Section 4.5 on transmission modes).

With regard to the target timescales of RK&M preservation, the overall consensus is "as long as possible". Nevertheless, the RK&M initiative found that different waste disposal project time frames entail different RK&M structures and that it is useful to make a differentiation between various phases. A timeline first developed within the NEA Reversibility and Retrievability project (NEA, 2011a: p. 31) was found useful and further developed by the RK&M initiative and the ICRP (ICRP, 2013) to indicate the relationship between disposal project implementation, oversight (see Chapter 2), and RK&M preservation time frames (see Figure 4.1).

Figure 4.1. **Relationship between disposal project implementation (in red and green), oversight (in black) and RK&M preservation (in blue) time frames**



The "short term" refers to the period of time that ends with repository closure. This period includes both the pre-operational and the operational phases of the repository. The "medium term" refers to the period of time with oversight activities that would follow repository closure. The "long term" refers to the period of time with no repository oversight.

The short term

In the scenario of final disposal followed by the RK&M initiative, the "short term" involves the actions of the construction, operation and closure of the repository facility. In this phase, the waste is still accessible (without major effort – depending on system design, this could be equivalent to the galleries not yet being backfilled) and "direct oversight" is possible. In the case of geological disposal, the galleries and shaft(s) are gradually sealed until there no longer is ready access to the underground facilities and the waste. The generations living in the short term are thus expected to complement and gradually replace "direct oversight" with "indirect oversight", which is exerted by more remote means (see Section 5.8 on the oversight provisions approach and the respective mechanisms in Annex 2.2). The short term thus includes both the pre-operational phase and the operational phase of the repository, up until its closure. In Figure 4.1, the short term is indicated to start with the siting decision. But from an RK&M preservation point of view, one could say it starts from the earliest radioactive waste management (RWM) discussions, or even from the earliest decisions to develop applications that produce radioactive waste (in light of contextual information).

For comparison, the "very short term", which the RK&M initiative defines as a period of time consistent with staff stability, foreseeable cycles of organisational change and explicit regulatory expectations of periodic safety reviews, is of the order of 10 to 20 years. Our definition of the short term thus firstly reveals that this period is in fact not that "short". In our daily life, "forever" is generally translated into the period of a lifetime or two or three generations, but in RWM and RK&M preservation, such a period is "short term". Secondly, the short term represents a dynamic phase in RWM, in which various actors play a role, important decisions are taken (e.g. how the repository is designed and finally constructed), various actions take place and enormous amounts of information (explicit and implicit, physical and tacit, structured and non-structured, theoretical and practical) are produced. Thus, it is a time in which a lot of RK&M is developed, but also rapidly lost if its preservation is not acted upon in a conscious, anticipatory and ongoing manner. The fact that this risk is real has been pointed out in the previous sections on RK&M loss (Section 3.2) and regulation (Section 3.3). The current focus for the short term is on archiving records in the immediate context of licensing requirements. Explicit recognition of the fact that some records are or should be produced not only to demonstrate compliance, but also to more generally inform both current and future generations, is still rather rare.

In summary, a challenge seems to consist in connecting the preservation of records with that of knowledge and memory across time, and the operational with the post-operational phase. Short-term RK&M preservation should be concerned both with supporting ongoing operational activities (the focus of the RepMet initiative)[40] and with preparing the future (the focus of the RK&M initiative) (NEA, 2014b; see also Section 6.3).[41] It is not only about creating information in an ad hoc manner, but also about proactively working on preserving it and sustaining its accessibility, comprehensibility and relevance (see also the description of the "memorisation" life cycle sub-process in Section 3.1). An approach with examples of mechanism mainly aimed at the short term (referring to Chapter 5) is knowledge management.

40. See the Vision Document of the Radioactive Waste Repository Metadata Management (RepMet) Initiative: www.oecd-nea.org/rwm/docs/2014/rwm2014-2.pdf.

41. The RK&M initiative exchanged thoughts with the Long Now Foundation on this issue, which critically addresses our societies' current short-term thinking (A. Rose in NEA, 2013: pp. 79-80). The Foundation aims to embody the idea of the "long now" among others by developing a clock designed to run for ten thousand years, symbolising engagement in each present. See: http://longnow.org/clock.

The medium term

The "medium term" refers to the period of time that starts after the closure of the disposal facility. In relation to Figure 4.1, this is the "post-operational" phase (in which the repository is designed to function without human intervention) for as long as oversight over the repository is carried out.

As "one might expect that society will maintain forms of indirect oversight … [for] as long as possible" (ICRP, 2013: p. 35), the medium term should be aimed to last. This is the key objective of RK&M preservation, to enable the continued prevention of uninformed actions related to the repository and the continued facilitation of informed action, should this be desired. Therefore, preparing RK&M preservation for the medium term in the short term and continuing RK&M preservation in the medium term is crucial. Nevertheless, the review of the RK&M bibliography (see Section 1.2) indicated that this period has often not been addressed as such. Most of the literature has dealt either with the present and operational period (i.e. the short term) or with an indefinite "long term". Yet, it may not be fruitful to talk about the larger timescales if the intermediate ones have not been addressed. A lack of success over decades or centuries is likely to imply a lack of success over millennia. This is also the reason for highlighting earlier in this volume the importance of planning responsibilities early over time (Section 3.3; see also Section 5.8 on the oversight provisions approach and the respective mechanisms in Annex 2.2).

While the notion of oversight may or may not involve subsequent action, it needs to be noted that oversight is an active concept. Oversight, both in its direct and indirect form, is more than sheer awareness of the repository's existence. It entails doing something with the records and the memories by means of knowledgeable actions. Oversight thus requires RK&M preservation, but it also generates it, as oversight actions will produce information that is likely to become part of and shape updated or new records, knowledge and memories.

An approach with examples of mechanism mainly aimed at the medium term (referring to Chapter 5) is culture, education and art.

The long term

In line with the recommendations of the ICRP, the RK&M initiative emphasises that loss of oversight is not planned. This is exactly what RK&M preservation is aimed at, but it is recognised that loss of oversight may happen at some time in the future after closure when society no longer keeps a watchful, caring eye on the facility (ICRP, 2013: pp. 31-32). This would be the phase referred to as the "long term" in the RK&M initiative.

In this phase, there may still be some awareness of radioactive waste repositories, but it is no longer acted upon by means of oversight, or there may be no more awareness at all. There may still be records, there may still be knowledge, or there may still be memory in society, but it could be fragmented. Its existence is no longer known, understood, or put to use. This implies that in order to allow any transmission of information in the long term, at least some RK&M must have the potential to be rediscovered in a timely manner to form the basis for RK&M reconstruction (see Section 4.5 on transmission modes). Although the facility is designed to be safe by itself, this reconstruction of RK&M and of oversight in its wake is desirable to continue to reduce the probability of inadvertent intrusion and enhance informed decisions about the facility.

Insights from archaeology, the study of the remains of the ancient past, are relevant for RK&M preservation for the long term, because it works to recover RK&M that has been lost. Archaeology also studies how the past is understood in the present, potentially yielding insights on how future societies could make sense of the remains of the past. Case studies such as an examination of megalithic tombs, show that the understanding of the past varies across time. It needs to be taken into account that archaeological interpretation (and historical interpretation in general) always reflects contemporary perceptions, which are socially and culturally embedded and mutable over time. Thus, it cannot be assumed that information, knowledge and meaning of the past can be fully and reliably transmitted into the long term. Based on this understanding, various specialists invited to the RK&M project made a case for trying to keep RK&M alive across time, continuously engaging each present and highlighting the importance

of the short and medium term. "Keep the long term in the back of your minds, but act notably for the short and medium term" was one of the pieces of advice (see C. Holtorf and A. Högberg in NEA, 2015: pp. 26 and 97-101).

In an ideal world, from an RK&M preservation perspective, there will be no "long term". If the long term did develop, it would be better if periods of no oversight were followed by periods of renewed oversight. RK&M mechanisms for the long term are aimed at raising awareness, especially when risks of inadvertent intrusion or uninformed decision making may come to the fore, and at subsequently allowing for RK&M reconstruction so as to avoid such risks from having negative consequences.

An approach with examples of mechanism mainly aimed at the long term (referring to Chapter 5) is that of time capsules.

4.3. **Multiple media**

On the simplest level of analysis, there are two interconnected aspects of RK&M preservation. There is the physical preservation of the information carriers or media, and there is the epistemic preservation of the content of information. This section deals with the former (Section 4.4 deals with the latter).

Referring to Annex 2.2 (the mechanism description sheets), tangible information carriers are for instance dedicated repository records; markers; archives, libraries, museums and their contents; and time capsules, industrial heritage, art works and maps. The analysis of the RK&M reference bibliography revealed that a lot of attention has been dedicated to the tangible component of RK&M preservation. Up until today, studies on the materials and technologies for records and markers that last as long as possible continue to be popular. Whereas in previous times, natural materials such as stone and paper were the most common information carriers, in the present day there is a wealth of potential media. The impact of the enormous advances in the technical possibilities of information and communication technology (ICT) on RK&M preservation across generations is, however, complex. In the last few decades the volume of generated information has increased enormously, whereas conversely, the lifetime of storage media – be it sound recordings, books, drawings, films, videotape, newsprint, magazines, photographs, monuments, 3D or computer-based documents – has strongly decreased.[42] On the one hand these modern media are indeed rather volatile, but on the other hand they make information available to society as never before.

Similar complexities exist with regard to digitisation. The main advantages are that it allows enormous quantities of data to be managed in a comparatively small space; it allows information to be easily duplicated; it reduces the handling of (original) analogue documents and therefore protects them; it offers added value with regard to readability and visualisation (higher resolutions, 3D imaging, etc.); it offers around the clock availability and multiple access; and it facilitates efficient information retrieval (the user is able to use any search term [word, phrase, title, name or subject] to search the entire collection[s]). Notwithstanding these clear advantages, there are also many challenges related to technical issues (media, formats, hardware, migration, etc.), continuity (maintenance, funding, etc.), access (organisation of records, tools to access information, etc.) and data protection. While digitisation allows for a dramatic increase in the possible ways to store and access information, digital information is also fragile and requires continuous care.[43]

With respect to current archiving practices, a 2012 survey sounding out RK&M group members' relationship with their national archives revealed that there still is a preference for archiving in analogue formats (e.g. permanent paper, microforms, or specific objects) (A. Claudel in NEA, 2013a, pp. 85-86). While in some cases archives are planned, either by the

42. See also: The dilemma of modern media – The Long Now Foundation www.longnow.org.

43. See also Palm, J. (2005), *The Digital Black Hole*. Available online from www.tape-online.net/docs/Palm_Black_Hole.pdf.

regulator or by the national archives, to be fully digital, at least with regard to material produced from the 21st century onwards (e.g. Switzerland, see K.W. Ohnesorge in NEA, 2012: pp. 27-28), other countries, for instance France, continue to favour paper (J-N. Dumont and P. Charton in NEA, 2012: pp. 28-29) or opt for a combination of digital and paper carriers (e.g. the United Kingdom). Permanent paper is estimated to last 600-1 000 years (J-N. Dumont and F. Espiet in NEA, 2015: p. 58). Other more durable materials have also been experimented with. For instance, Andra, the French implementing agency, supported the development of a sapphire disk, which can contain in large numbers of records and is estimated to endure up to a million years (A. Rey in NEA, 2013a: pp. 81-85). The Radioactive Waste Management Funding and Research Center (RWMC) in Japan also performed an experimental study into the durability of engraved messages and concluded that silicon carbide is a promising long-term recording medium (Kazutoshi et al., 2003).

Engineering issues were also studied beyond records alone for other tangible mechanisms such as time capsules and markers. Focusing on materials as well as cost effectiveness, the WIPP programme for example, is considering native stone materials for its markers that stand up well over time in the environment of the repository (A. Van Luik in NEA, 2012: p. 92). Other thoughts have also gone in the direction of using non-native materials, to highlight the man-made nature of the repository site. In any case, historical examples (such as Japanese tsunami stones, Stonehenge, the megalithic temples of Malta and the pyramids) indicate that the concept of long-lasting markers (from a few hundred to a few thousand years) is feasible (NEA, 2014a: p. 7). Large and heavy markers are hard to move through natural forces and there must be a strong will to move or destroy them if mankind takes on that task. It must be presumed, however, that they have a finite life, whose timespan is difficult to define and would depend on the local circumstances. On the other hand, markers could also be replaced with new ones over time. In Japan, for instance, new tsunami warning stones were erected after various tsunamis (NEA, 2014a: p. 7; see also Section 5.4 on markers).

It has been suggested that radioactive waste itself can also be seen as a tangible information carrier ("radioactive memory … [transmitting] knowledge"), by allowing "distant civilisations" to infer the time which has passed since disposal (W. Ernst in NEA, 2013a: pp. 44-47). On a shorter timescale, art has been proposed as a medium to visualise and thus communicate the phenomena of radiation and radioactive decay, for instance in the form of a marker that serves as a counter (Thomson and Craighead in NEA, 2015: pp. 133-135) or as a fading colour on the outer building of a surface facility (H. Codée and E. Verhoef in NEA, 2015: pp. 53-56, see Figure 7).

Apart from non-human (material or technological) media, humans obviously are also information carriers, through their knowledge and memories. People can carry and share information in an intangible manner via knowledge management, education, conventions, oral traditions (e.g. storytelling, songs), rituals and commemorations.

Most intangible mechanisms also make use of some tangible components (e.g. education with textbooks, local history in local newspaper articles, song recordings, international co-operation laid down in written agreements). One could say that all tangible mechanisms have intangible components. This relates back to the title of the RK&M project: records and material information carriers in general in themselves have limited meaning without the ability to understand and utilise the data and information they carry (knowledge), which in turn requires awareness of their existence and the reason for their existence and benefits from a broader awareness of events, people, places and levels of knowledge in the past (memory).

Overall, there is agreement that the media used needs to be selected based on their durability and the readability and accessibility of the information they contain (see also J-G. Nokhamzon in NEA, 2013a: p. 103). While intuitively we may think of tangible information carriers as being preferable over intangible media in these aspects, evidence is not unanimous here.[44] There are instances where oral traditions have beaten written ones with regard to both life span and reliability. There are also instances where it was the intangible component that ensured the effectiveness of the tangible component. An example, the Japanese tsunami stones. Some over thousands of years old thus materially robust, they have proved effective in warning people not

44. See for instance: www.historyofinformation.com/narrative/oral-to-written-culture.php.

to build houses below a certain altitude only in places where the marker itself was complemented by commemorations, teachings in schools and a general respect for ancestors (NEA, 2014a) (see also Section 5.4 on markers).

Based on the findings of the RK&M initiative, it is thus recommended to include both tangible and intangible media when developing an RK&M preservation strategy. preferably in an indexing and combining way (for instance retiring staff not only leave their records but also talk to their successors and show them how to exert certain skills such as, commemorations take place in the vicinity of the repository, markers are integrated in educational field trips, rituals are built around for instance measurement campaigns, etc.).

4.4. Multiple contents

We now move from the physical preservation of the information carriers or media to the epistemic preservation of the content of information. Interestingly, it was discovered that working with sapphire disks created more questions than it solved. In fact, the purpose of further developing the device became to question "solutions" that are solely based on engineering, as it evoked questions such as: Which languages should we use, which graphical material should we add, what meaning will future generations give to the traces we leave, and should information be updated? (J-N. Dumont & P. Charton in NEA, 2012: pp. 28-29). The US marker programmes had similar experiences, as uncertainties with regard to symbolic and semiotic durability were found to be at least as persistent as those related to the material durability (see Hora et al., 1991 and Trauth et al., 1993). In summary, the long-term material and technological durability of information carriers and the long-term persistence of the messages and meaning they carry need to be studied together (see also Section 4.6 related to involving multiple disciplines). Readability (legibility and language) and understandability (comprehension and context) are the key topics of the field of "nuclear semiotics". While it goes beyond the scope of the RK&M initiative to go into detail, combined with the fact that the content of RK&M will always be repository and context dependent, some guidelines of a more generic nature are nevertheless useful for designing a RK&M preservation strategy.

Firstly, as pointed out before, the RK&M initiative recommends information that is descriptive rather than prescriptive and informative rather than emotional. While the information we produce will inevitably reflect our opinions and desires to a certain degree, this should not be the aim (for instance scaring people off or dictating what people should do). RK&M preservation across generations is hinged on future generations' right to access to environmentally and historically valuable information, not on imposing our opinions about what future generations should do with this information. The RK&M initiative recommends taking a participatory and iterative approach when designing the content of RK&M to be preserved in order to elicit various perspectives on how the aims of protecting and informing can be best translated (see Section 4.6 on actors).

Secondly, taking into account the different timescales and different potential audiences, it is recommended to develop information ranging from basic to detailed, from generic to expert and from contextual information to exact data. It has been suggested that a reflective approach could be considered in this regard, deciding which RK&M should be preserved, at what level of detail, and how, by examining what the value of the information would be for various audiences (NEA, 2015: p. 27). Also in this regard, a participatory and iterative approach is recommended. Connected to the fundamental objectives and principles of RK&M preservation (see Chapter 2), the following indications may be insightful when designing a RK&M preservation strategy.

- To prevent inadvertent intrusion by future generations by maintaining awareness of the repository over long time frames, RK&M preservation approaches may focus on more basic information by means of for instance symbols, images and maps. These mechanisms should point people to more elaborate information as much as possible, related in the first place to the location of the facility, the design of the waste management system (containers, barriers, facility structure, etc.) and the hazards associated with its content.

- To support informed decision making (and consequent action if judged desirable by future generations) by preserving knowledge about the repository (or the possibility to regain it), RK&M preservation approaches would focus on more detailed information by means of (multiple) languages, graphs, figures and plans. This information would enrich the first level of information).
- To enable insight into past reasoning and activities by means of preserving memory of the repository and its context, RK&M preservation approaches may focus more on contextual information, by means of for instance stories, documentaries, objects, drawings, and photographs. This information would enrich the first and second levels of information as set out above.

It is acknowledged that the interests and skills of future generations can change rapidly and it is speculative to define what future generations want or need to know with respect to a repository (NEA, 2012: p. 31). Consequently, potential information requests of these generations are not predictable, but can at most be approximated based on potential questions and the needs of today. The thinking within the RK&M initiative was thus hinged upon collecting and developing ("memorising", referring to Section 3.1) information that is likely to answer questions that we ourselves can imagine posing when dealing with a waste repository that we did not develop ourselves, while keeping an open mind to any other questions that may arise. Three potential interests have been defined within the RK&M initiative (see NEA, forthcoming-b), under which a variety of other possible reasons can be identified:

a) Future generations want to perform their own long-term safety assessment

The interest is directly connected with the wish of a future generation to identify potential hazards connected with the facility on their own, whether or not connected to subsequent remedial actions or alternative RWM technologies or procedures. Future generations might follow the information from a safety case produced by previous generations, but it is plausible that they prefer applying their own methods and tools.

b) Future generations want to trace back decisions from the implementation process

This interest may include questions such as: where does this waste come from, why was it decided to dispose of it in a deep geological repository, why is it deposited at particularly this site, who was involved in the decision-making process and how was the repository constructed and sealed?

c) Future generations want to retrieve material from the repository

This interest is a requirement in regulations of some countries, namely that a retrieval of waste containers from a repository should be possible for a given time after repository closure. Such an interest might turn out not to be restricted in time and may also extend to the retrieval of other material than the waste itself (e.g. copper).

These potential interests are also the backbone of a selection procedure put forward in the course of the RK&M initiative as an example, to illustrate how the processing of a huge amount of records to compile a "set of essential records" (see Section 5.2) could be put into practice.

4.5. **Multiple transmission modes**

The historical review of RK&M thinking brought two main RK&M transmission modes to the fore (see Section 1.2). One perspective focuses on the creation of a *mediated* link, *via* next generations, through human (societal) RK&M transfer mechanisms (e.g. education and regulation). The second emphasises the creation of a *direct* link to future generations through more technical RK&M devices (e.g. markers and time capsules). While the first approach would work with changing social (e.g. economic, political and cultural) contexts over time, the second would aim to be as independent as possible from changing contexts. The RK&M initiative refers to these

transmission modes as "mediated" and "non-mediated" respectively.[45] In the case of mediated transmission, where information is successively passed on from one generation to the next, each generation may undertake steps that affect the continuity of availability (related to the medium) and readability or understandability (related to the content). Non-mediated transmission places no reliance on the presence of intermediaries. In this latter case, information and its carrier are developed to be delivered directly from the present time to the future receiver.

Tangible information carriers can be the object of both mediated and non-mediated transmission. Intangible information carriers can only be the object of mediated transmission. Records can be transferred in both a mediated and a non-mediated manner. Memory can too, but only when translated into a tangible form (e.g. diary writings, newspaper articles, pictures, etc.). Knowledge, because it involves a learning process which results in a skill, is transferred more easily in a mediated way (e.g. explaining and showing how to do something), but non-mediated transmission is also feasible as long as the content of the tangible medium can be interpreted (e.g. manuals, instructions, dictionaries and videos). The latter was investigated during the RK&M project. According to knowledge management experts, knowledge can be (J. Day and E. Kruizinga in NEA, 2013a: pp. 57-61):

- Maintained: this refers to active knowledge management (e.g. by training people). This requires people, economics, processes and impetus (commercial, intellectual, regulatory, moral, cultural).
- Consolidated: this refers to gathering, structuring and culling knowledge to a point at which you reach the minimum from which you can later reconstruct knowledge.
- Mothballed: this refers to the preservation of "consolidated knowledge". It is about the preservation of tangible knowledge carriers combined with mediated transmission via regular training/teaching activities.
- Reconstructed: this refers to building full knowledge readiness from mothballed knowledge.
- Innovated: this refers to using knowledge for learning and innovation.
- Forgotten: this can be a passive, but also an active process (e.g. learning to do something differently).

"Knowledge mothballing" thus refers to the conscious consolidation of knowledge for later use, as such addressing the possibility of periodical limited interest. Currently, it has been proposed as a knowledge retention strategy for the short term only (possibly over 100 years). While an extension to the medium term seems plausible, it is not applicable for the long term, since the long term, as defined in the RK&M initiative, implies that mediated transmission is no longer taking place. However, history does seem to indicate that long-term "mothballing" is possible too, for instance through combinations of documents (to which a deciphering key can also be added, like the Rosetta Stone[46]), archaeological artefacts and the human stamina to reconstruct information and knowledge. Mediated and non-mediated transmission phases can also alternate. This would also be the case if, for example, markers are renovated.

It is not recommended to rely on non-mediated transmission alone. Attempting to decide at the present time how to organise and preserve meaningful information for generations in the very distant future has been described by multiple experts contributing to the RK&M initiative as a rather utopian undertaking. A mediated approach to maintaining information would allow for adapting the methods and techniques for RK&M preservation to be consistent with generations at specific intervals in time, thus helping to address the uncertainty associated with the level of sophistication of future generations. One important aspect of this mediated approach should be

45. The distinction is related to what is referred to as "Active" and "Passive Institutional Controls" in the United States. See the US entry in NEA, forthcoming-a; and also Annex 1: RK&M glossary).

46. Two projects presented by external speakers at RK&M project meetings are developing such a device, the Long Now Foundation (http://rosettaproject.org) and the Memory of Mankind (www.memory-of-mankind.com).

educating younger generations about radioactivity and nuclear waste matters (NEA, 2015: p. 27; see also Section 5.6). Foreseeing recurring reviews with regard to understandability over time are also recommended, which entails that RK&M preservation strategies will need to be flexible and adaptable over time.

Although information adaptation can also be seen as a threat (information becoming deviant or defective), the advantage of non-mediated over mediated transmission is not decisive in this regard, in light of context loss and misinterpretations. There are also examples where mediated transmission has exactly ensured the preservation of the original information. A particular case in this regard is Ise Jingu, a Shinto shrine in Japan. Every so many decades one shrine is deconstructed as another one is constructed, thus keeping both an identical yet maintained shrine over time and the skills and rituals to build and use it alive.[47]

On the other hand, mediated transmission relying on a "rolling future" (C. Pescatore and C. Mays in NEA, 2012: p. 97) involves the vulnerable requirement of a chain of responsibilities. The breaking of such a chain cannot be excluded. Therefore it is recommended to also study and develop non-mediated mechanisms that would be less vulnerable to changes in social conditions and may be less reliant on institutional presence. The timescale under consideration needs to be taken into account and the arrival of the "long term" (see Section 4.2) should not be ruled out.

In conclusion, the recommendation is to adopt a "dual-track strategy". A strategy that combines mediated and non-mediated RK&M preservation mechanisms would take advantage of the opportunities provided by a continuing intergenerational chain and concurrently address the challenges of reaching out to the further generations in case the intergenerational chain ceases to be functional at one point. As such, it addresses both continuity and discontinuity in the functioning of society in the future. The two tracks may address different target audiences, different timescales and different levels of detail. As for tangible and intangible carriers, hybrids of mediated and non-mediated methods are also recommended. For example, time capsules may be planned to be opened (and resealed) on a regular basis, incentives for the upkeep of markers can be developed and the responsibility for preserving records in their original format can be transferred from one generation to the next.

It also needs to be mentioned that while some transmission modes need to and can be developed and implemented in a dedicated, intentional way (e.g. regulation dedicated to RK&M preservation or a specific time capsule), others may come into being in a more unintentional way (e.g. surface traces left in the landscape due to the disposal activities or storytelling).

4.6. **Multiple actors**

In the past, research and policy making in the nuclear field was typically grounded on a split between "technical content" and "social context", with a strong division of labour between natural and social scientists and a division of competences between experts and the public (Turcanu et al., 2016). In more recent years, however, the need for multidisciplinary research and broader societal involvement is increasingly recommended at national as well as supranational levels.[48] The RK&M initiative's recommendations are no exception in this regard. On the contrary, since the topic of RK&M preservation so unmistakably requires and involves a variety of insights and players at the production, preservation, as well as the access level (see Section 3.1), it may even offer a platform for innovative forms of engagement and mutual learning.

47. See www.isejingu.or.jp/en/ritual/index.html.

48. See www.oecd-nea.org/civil or broadened beyond the nuclear context toward science and technology in general: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society.

Multiple disciplines

RK&M preservation poses and addresses challenges of a more technical as well as a societal nature, both with regard to its content and preservation. Therefore, it is a task that requires multiple disciplines to work together. Different specialists can investigate, develop and implement different aspects of the same topic (e.g. material, legal, societal and managerial), by means of various methods (e.g. quantitative/qualitative, top-down/bottom-up) with different strengths and weaknesses. In fact, RK&M preservation requires an "interdisciplinary approach", where results are not only added up after various disciplines did "their part of the job", but where multiple disciplines interact and collaborate to combine their work as one joined-up activity. For instance, engineers interested in the long-term material and technological durability of information carriers and semioticians interested in the long-term societal and cultural durability of messages will need to interact and understand each other's goals and concerns. Messages need appropriate media and media needs appropriate messages. Engineers and semioticians thus mutually shape each other's tasks. Overall, "system development has to be understood, not just the development of single elements" (M. Buser in NEA, 2012: p. 31). Lay knowledge from local community[49] members is an important field of expertise that should not be neglected in RK&M preservation (see also page 78, Footnote 72 on "citizen science").

The RK&M initiative itself benefited from a multidisciplinary composition with members' backgrounds and competences including physics, chemistry, geology, engineering, data management, history, philosophy, social studies of science and technology, conservation, archival science, museum studies, public management, environmental science, regulation and licensing, safety science, and programme management. Additional external expertise was sought among others in the fields of knowledge management, (landscape) archaeology, cultural heritage studies, material sciences, archiving and art. By reaching out to specialists that are not typically represented in waste management organisations, the initiative made a start with involving and engaging new groups of people in the field of nuclear waste disposal and RK&M preservation and started to build bridges between disciplines that otherwise rarely collaborate. This inter-disciplinarity helped to address and develop RK&M preservation as a task in which technical, scientific, societal and cultural information is interwoven, and where a variety of both more technical and more social methods should be assessed and deployed (NEA, 2011b).

Multiple interests, concerns and roles

RK&M preservation across generations is an effort that needs to combine the workings and insights from institutional, professional and academic spheres and from everyday life. As such, it does not only require an "interdisciplinary", but also a "transdisciplinary" approach, which refers to an appreciation of insights and knowledge beyond disciplines and beyond academically or professionally defined expertise. Such an approach is more commonly known as a "participatory" or "stakeholder involvement" approach. It entered the nuclear field in the context of the siting of radioactive waste repositories (see the European projects COWAM[50] and CARL[51]), but is currently spreading to the broader fields of nuclear safety and radiation protection too (e.g. the new NEA division of Radiological Protection and Human Aspects of

49. The definition of "local community" adopted by the FSC is "a societal group of any size whose members reside in a specific locality, usually share a government and often have a common cultural and historical heritage" (NEA, 2013b). "An Annotated Glossary of Key Terms" available online from: www.oecd-nea.org/rwm/docs/2013/6988-fsc-glossary.pdf). This specific locality in this case refers to the repository site, which is why the term "host community" is sometimes also used.
50. Community Waste Management www.cowam.com.
51. Citizen stakeholders, agencies responsible for radioactive waste management, social science research organisations, and licensing and regulatory authorities http://uahost.uantwerpen.be/carlresearch/index.php?pg=6.

Nuclear Safety, RP-HANS [52] or the EC-funded project ENGAGE [53] and the annual RICOMET conferences[54]). Its relevance is also recognised by the ICRP, which states that the path for a sound optimisation process for geological disposal systems should be understood and organised as "a stepwise process where all involved stakeholders can judge the result of the optimisation process and indicate ways to improve various elements of the system" (ICRP, 2013: p. 46).

A stakeholder is defined as any actor (institution, group or individual) with an interest, concern or role to play in the radioactive waste management related RK&M preservation process (see Annex 1: RK&M glossary). Implying all RK&M preservation life cycle sub-processes (production, preservation and access, see Section 3.1), this involves a very large variety of actors with different roles to play over time, both public and private, at the local, regional, national and international level, including:[55]

- implementing agencies;
- regulating agencies;
- waste producers;
- governments;
- researchers and specialists in various disciplines;
- policy makers;
- international agencies;
- local communities;
- interest groups (e.g. non-governmental organisations and lobby groups);
- memory institutions;
- teachers and trainers at various levels and in various disciplines.

Being involved in and contributing to RK&M preservation is something other than being responsible. A survey among RWMC members carried out as part of the RK&M initiative in 2011 indicated implementing agencies, regulators and governments as the actors that carry the main, formal responsibilities for RK&M preservation, at least up until repository closure. Depending on the national situation, national archives are also formally involved (see also Section 5.3 on memory institutions and the corresponding mechanism in Annex 2.2). For the post-operational phase, the ICRP states the following: "In the post-operational period, after the end of active regulatory oversight, maintaining indirect oversight and memory of the facility should become a societal responsibility, possibly discharged through national or local government" (ICRP, 2013: p. 35). If oversight is to become a "societal responsibility", it is participatory in nature and requires ongoing dialogue to periodically renew the basis of understanding among stakeholders (Pescatore et al., 2013). Local communities were mentioned multiple times throughout the RK&M initiative as potential long-term actors in the preservation of RK&M, due to their proximity to the repository and because they are thought to be a group well positioned to express possible or imagined concerns from individuals from society in a distant future (M. Jensen in NEA, 2013a: p. 110). On the other hand, it was also pointed out that there may not be a local community at all disposal sites, today or in the future (see A. van Luik in NEA, 2012: p. 32). This supports the recommendation to involve multiple stakeholders in RK&M preservation in a context-sensitive manner. It is particularly recommended to look for synergies with societal institutions and bodies,

52. www.oecd-nea.org/hans.

53. Enhancing Stakeholder participation in the Governance of radiological risks for improved radiation protection and informed decision making, www.engage-h2020.eu.

54. International conference on risk perception, communication and ethics of exposures to ionising radiation, http://ricomet2018.sckcen.be.

55. To get more insight in the variety of actors (potentially) involved in RK&M preservation, please check the section on "actors" in the various mechanism description sheets in Annex 2.2.

also internationally, that are likely to survive beyond the closure of the repository (which is unlikely for the repository operator). Actors involved in mechanisms outside RWM can also foster disposal related RK&M preservation. Radioactive waste disposal RK&M preservation programmes need not be developed in isolation from other programmes such as, for example, information preservation, environmental monitoring and heritage conservation. Having both actors that have a personal interest (or passion) in preserving RK&M as well as actors, such as formal institutions or organisations, that are either paid or required by law to preserve RK&M are considered to add to the strength of an RK&M preservation strategy.

In conclusion, it is recommended to take a participatory approach in designing, developing and implementing a systemic RK&M preservation strategy, both with regard to its content and its approaches. A participatory approach is believed to support diversity and redundancy by eliciting various perspectives on how the fundamental objectives of protecting humans and the environment and supporting informed decision making can best be translated, and by enabling RK&M to be carried by as many and various actors as possible (see also Section 6.5).

4.7. **Multiple locations**

This chapter has so far explained and promoted diversity and redundancy in RK&M preservation mechanisms in terms of timescales, media, contents, transmission modes and actors. This last section explains why involving multiple locations (the local, regional, national and international level) is also a key characteristic of a systemic RK&M preservation strategy. It relates to where to preserve RK&M (e.g. where to build a marker, where to build an archive, where to keep a key information file (KIF), where to monitor, etc.), but it also relates to the scope of RK&M preservation mechanisms, which should incorporate the benefits of both local specificity and international standardisation.

Radioactive waste-related information, in all its forms, is often scattered among a large variety of places, such as with waste producers, in off-site commercial storage facilities, in research institutes, with implementing agencies, nuclear regulators, local and national authorities, and online. On the one hand, this forms a threat for RK&M preservation over time because such a spread may induce loss, forgetfulness and inaccessibility, and stand in the way of "getting the full story". Moreover, while some locations may have some sort of RK&M preservation policy in place, others may only have short-term interests, unrelated to RK&M preservation across generations. On the other hand, preserving RK&M in multiple locations is also a recommendation of the RK&M initiative. It aids location-sensitive diversity in the sense of having "the right mechanism in the right place" (e.g. a marker at the disposal site, a KIF [see Section 5.2] in the city hall and local library, detailed location information in the regional cadastre, a set of essential records [idem] at the national archives, the uptake of repository information in international inventories and catalogues, and online maps). A high frequency of RK&M locations also promotes redundancy, permitting some sources to be lost without losing the overall functioning of the system.

It is thus a matter of both duplicating the same RK&M at different places and of having multiple RK&M mechanisms with different key characteristics tailored to different stakeholders in different places in society. As such, all the various mechanisms in the various locations form a RK&M preservation system that is more than the sum of its parts. Varied mechanisms at varied locations can be designed to be integrated (e.g. international guidelines and national regulation) or complementary (e.g. markers and alternative land use) and act as indexes to each other (the KIF can, for instance, refer to the location of the SER), thus strengthening the overall RK&M preservation system and the quality of information.

Two spatial levels received particular attention throughout the RK&M initiative, the local level (see also previous section on actors) and the international level. The initiative was established at the NEA based on the idea that a concerted approach at the international level would contribute to the further development of national RK&M preservation strategies. More generally, the relevance of the international level for RK&M preservation across generations relates also to the volatility of national boundaries over time. Involving international mechanisms in addition to national mechanisms constitutes an element of redundancy in this regard.

Awareness of the value and vulnerability of RK&M preservation is already reflected by a number of international mechanisms outside RWM, notably related to the fields of geology and geography (e.g. the Infrastructure for Spatial Information in the European Community [INSPIRE]), environmental protection (e.g. the Aarhus Convention mentioned earlier [see Footnote 35 on page 43]), and cultural heritage preservation (e.g. the UNESCO World Heritage Convention and Memory of the World programme – specifically for documentary heritage, see also J. Springer in NEA, 2013a: pp. 87-88). These international mechanisms can constitute a potential resource, both theoretically (by means of insights into their functioning and the standards they deploy) as well as practically (by means of real collaboration) for RK&M preservation in the field of RWM (see also Section 5.9 on international mechanisms).

In summary, approaching RK&M preservation across generations from an international angle is advisable in light of the long time frames and an internationally shared concern for protecting humans and the environment and informing future generations. Some specific ideas have already been proposed (e.g. to collaborate with the UNESCO Memory of the World Programme), to develop some type of international markers or to indicate disposal sites on international maps with a common symbol (see also Section 5.9 on international mechanisms and the accompanying mechanisms in Annex 2.2; see also the dedicated field ("International Dimension") for all mechanisms in Annex 2.2). Such ideas can be seen as a means to create a link between disposal sites across the world (e.g. NEA, 2015: p. 26). However, national and local contexts cannot and should not be disregarded. The RK&M initiative promotes international collaboration and a level of procedural standardisation (e.g. to provide a regulatory framework, to produce a KIF and the minimum content it should have, to appoint responsibilities in terms of land use controls, etc.), but this does not have to entail a standardisation of practices. RK&M preservation approaches and mechanisms cannot simply be copied from one location to another. Moreover, from a regulatory point of view, it is likely to be the state that has ultimate responsibility for radioactive waste repositories and it is likely the local and regional levels, being directly affected, that have the keenest interest in the preservation of RK&M preservation over time. Standardisation offers opportunities (such as international recognisability and collaboration), but attention is needed for potential pitfalls too (e.g. the pitfall of a bad standard). This again highlights the value of a systemic RK&M strategy with diverse and redundant approaches and mechanisms that also combine the benefits of both local specificity and international standardisation.

4.8. References

Hora, S.C., D. von Winterfeldt and K.M. Trauth (1991), *Expert Judgement on Inadvertent Human Intrusion into the Waste Isolation Pilot Plant,* SAND90-3063 UC-721, prepared by Sandia National Laboratories for the US Department of Energy, Albuquerque, New Mexico and Livermore, California.

ICRP (2013), *Radiological Protection in Geological Disposal of Long-Lived Solid Radioactive Waste*, ICRP Publication 122, Annals of the ICRP, Vol. 42/3, pp. 1-57.

Kazutoshi, S. et al. (2003), "Record Preservation Study on Geological Disposal: Significance and Technical Feasibility", RWMC Technical Report RWMC-TRE-03001, Radioactive Waste Management Funding and Research Center, Tokyo.

NEA (forthcoming-a), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Catalogue of Legislation, Regulation and Guidance Governing the Preservation of RK&M for Radioactive Waste Repositories*, OECD, Paris.

NEA (forthcoming-b), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Compiling a Set of Essential Records for a Radioactive Waste Repository*, OECD, Paris.

NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate,* OECD, Paris, www.oecd-nea.org/rwm/pubs/2015/7259-constructing-memory-2015.pdf.

NEA (2014a), "Markers – Reflections on Intergenerational Warnings in the Form of Japanese Tsunami Stones", NEA/RWM/R(2014)4, www.oecd-nea.org/rwm/docs/2014/rwm-r2014-4.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 (RWMC), www.oecd-nea.org/rwm/rkm/documents/flyer-A4-rkm-collective-statement-en-2014.pdf.

NEA (2013a), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding", www.oecd-nea.org/rwm/reports/2013/rwm-r2013-3.pdf.

NEA (2013b), "An Annotated Glossary of Key Terms", www.oecd-nea.org/rwm/docs/2013/6988-fsc-glossary.pdf.

NEA (2012), "The Preservation of Records, Knowledge and Memory (RK&M) across Generations: Scoping the Issue: Workshop proceedings", www.oecd-nea.org/rwm/docs/2012/rwm_r_2012_6.pdf.

NEA (2011a), "Reversibility and Retrievability (R&R) for the Deep Disposal of High-level Radioactive Waste and Spent Fuel: Final Report of the NEA R&R Project (2007-11)", www.oecd-nea.org/rwm/rr.

NEA (2011b), "Preservation of Records, Knowledge and Memory across generations. A Collective Statement of the NEA Radioactive Waste Management Committee (RWMC)", www.oecd-nea.org/rwm/rkm/documents/rkm-collective-statement-2011-en.pdf.

Pescatore, C. et al. (2013), "Oversight of a deep geological repository and the role of monitoring – Some preliminary findings within the RK&M project of the NEA", paper presented at the MoDeRn International Conference, 19-21 March 2013, Luxembourg.

Schröder, J. (2015), "Geological disposal of radioactive waste: A long-term socio-technical experiment", *Science and Engineering Ethics*, Vol. 1–19, http://dx.doi.org/10.1007/s11948-015-9650-4.

Trauth, K.M., S.C. Hora and R.V. Guzowski (1993), *Expert Judgement on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant,* SAND92-1382 l UC-721, prepared by Sandia National Laboratories for the US Department of Energy, Albuquerque, New Mexico and Livermore.

Turcanu, T. et al. (2016), "Like a bridge over troubled water – Opening pathways for integrating social sciences and humanities into nuclear research", *Journal of Environmental Radioactivity*, Vol. 153: pp. 88-96.

Chapter 5. **RK&M preservation approaches and mechanisms**

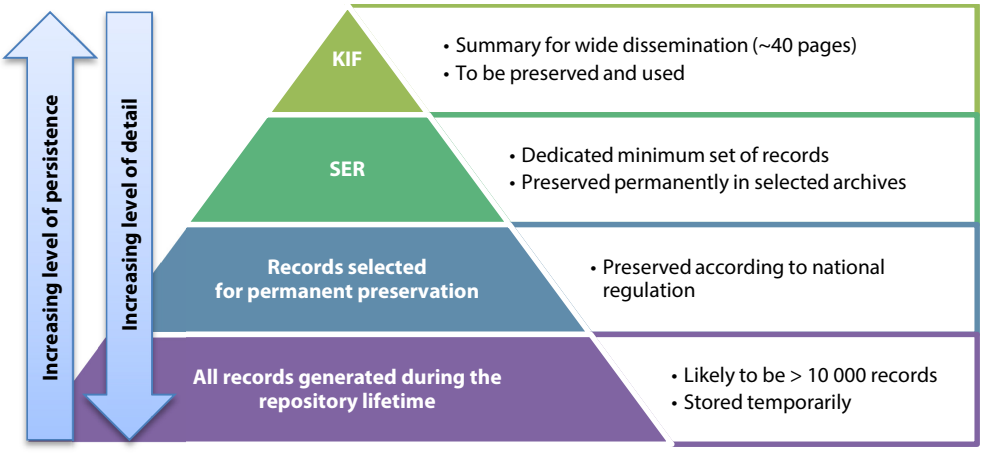
5.1. **Introduction to the RK&M preservation "toolbox"**

The RK&M initiative elaborated 35 mechanisms grouped into 9 broad approaches to RK&M preservation. The approaches and the individual mechanisms are in themselves, with a few exceptions, not new. What is original is how to use and apply them within an RK&M preservation strategy. They were especially selected and elaborated in light of offering various building blocks for a systemic RK&M preservation strategy. The common denominator of all these approaches to RK&M preservation is their aim to avoid inadvertent intrusion into a repository and to support informed decision making for as long as possible. However, they provide diversity with regard to the ways that they address these aims. In other words, they vary with regard to their key characteristics, as discussed in the previous chapter.

While some overlap is inevitable and also desirable from a systemic point of view, this variety is meant to support the overall strength of the RK&M preservation system. The RK&M initiative emphasises that even if it is advertised in the individual mechanism descriptions, a single mechanism will not achieve much in terms of RK&M preservation across generations. A systemic strategy is to be understood as a network of various mechanisms that are interconnected and work together (see Chapter 6). The combination of approaches and mechanisms should aim to keep the story of the repository alive to allow people, today and in the future, to know and to understand the where, what, how and why of the repository and its content on a generic level, as well as to point to where more specialised and detailed information can be found.

The remainder of this chapter gives a description of the nine approaches in a non-hierarchical order. Some descriptions are longer than others, which also does not correspond to their importance, but to the number of examples encountered and the studies conducted throughout the RK&M initiative. The respective mechanisms that belong to each approach and some of their key characteristics are displayed in small tables at the end of each section (Tables 5.1-5.9). Their full descriptions can be found in Annex 2.2. A full overview table that encompasses all key characteristics of the different mechanisms grouped into approaches can be found in Annex 2.3, also available on line at www.oecd-nea.org/rwm/rkm.

Figure 5.1. **KIF and SER in the overall scheme of repository records**



5.2. Dedicated record sets and summary files

Over the lifetime of a repository, starting with its planning, enormous amounts of information and data will be produced. Implementing agencies in most countries are legally required to generate and retain large amounts of records about the radioactive waste disposal projects they are involved in. In line with the goals of protecting and informing future generations, this information needs to be transferrable, accessible and digestible for and by a variety of actors over time. Unstructured, scattered or tacit records will not support this need, nor will archives filled with overwhelming amounts of technical data, implementer decision-reports and regulatory decisions which are hardly accessed or even known.[56]

Besides reducing the risk of a "keep everything, find nothing" situation (see Section 3.2), the reduction in scale of the records has the advantages of opening the potential for the production of more copies and the use of more durable materials (both aimed at enhancing spread, accessibility and longevity), but it also carries a threat of information loss or bias. Information selection and structuring therefore requires a dedicated and deliberative approach. It should not be delayed and the processes and products should be reviewed and tested by various actors, both on the side of the producers and the (proxy) receivers (e.g. engineers, local community representatives, teachers and mining companies) (see also the role of the "curator" in Section 3.1). The RK&M initiative aimed to open the way by means of outlining two mechanisms dedicated to scale reduction, workability and accessibility, namely the creation of a KIF and the compilation of a SER. Both concepts are the subject of dedicated, separate reports (NEA, 2019 and NEA, forthcoming-b) and have been developed as mechanism sheets too (Annex 2.2). Figure 5.1 offers a visual representation of both concepts in the overall scheme of repository records.

A Key Information File (KIF) (see NEA, 2019) would be a single document, produced in a multidisciplinary and participatory manner, meant to inform present and future people without specialised knowledge. Such a file would be widely distributed in many copies (e.g. town hall, libraries and websites of international agencies). It is meant to provide an overview of the disposal project in a concise form, containing basic information on the repository and the waste it contains, as well as a summarised history of decision making. This information is intended to be sufficient to allow society to understand the intent of the repository and to reduce the likelihood of uninformed human intrusion. The KIF is a summary document. It should also point to mechanisms that preserve more detailed information (among others the Set of Essential Records [SER], NEA, forthcoming-b) about the disposal facility, its content and associated safety cases.[57]

An SER (see NEA, forthcoming-b) is designed to be a unique set of actual records, selected during the repository lifetime, aimed at providing sufficient information for current and future generations to ensure an adequate understanding of the repository system and its performance, and thus to allow informed decisions to be taken with proper assessment of the consequences.

56. The challenge of how to reduce the very large amounts of information produced throughout the planning, development and implementation phases of disposal projects to the required level without being overwhelming was already identified during the preparation of the establishment of the RK&M Initiative (see Section 1.1). A questionnaire was prepared to gauge RWMC member's interests, existing activities and national frameworks related to the field. Responses (provided by implementers and regulators from 12 countries) related to which information and memory should be preserved including the nature of the hazard, detailed records of site construction and waste emplaced, and "meta-information" understood as non-technical information about the basis for past decisions. Most respondents thought that both summary and detailed information should be preserved (see NEA, 2010). These preliminary indicators formed the very early basis of the KIF and SER ideas explained further in this section.

57. The KIF concept is being trialled through the preparation of draft documents for the WIPP in the United States (deep geological disposal), the planned final repository for spent nuclear fuel at Forsmark in Sweden (deep geological disposal) and the closed Centre de la Manche facility in France (surface disposal) (see annexes to NEA, 2019). These summaries are currently under development by the respective implementing agencies and are to be finalised in a multi-disciplinary, participatory manner in the future.

The size of the SER for any disposal facility will likely be determined by local regulations and requirements, with the goal of containing the records generated during the repository's lifetime that are essential to fulfil those purposes.[58]

While the KIF as well as the SER are both designed to provide essential information about the repository to future generations, they are autonomous tools that should be developed, managed and maintained independently. They have different focal points and target audiences (see above), are faced with different opportunities and challenges, may be managed and preserved under different responsibilities, are likely to be used differently and stored in different environments. These two mechanisms are considered prime examples of RK&M tools that complement each other, provide for diversity and act as indexes towards each other (see also Chapter 6).

Table 5.1. **Dedicated record sets and summary files: Mechanisms overview table**

Dedicated record sets and summary files				
			Key information file (KIF)	Set of essential records (SER)
Scope	RK&M type	Information	x	x
		Records	x	x
		Knowledge		
		Memory	x	
		Awareness		
	Level of detail	Low level of detail	x	
		High level of detail		x
	Geographical scope	Local	x	x
		Regional	x	x
		National	x	x
		International	x	
		Virtual		
Characteristics	Intentionality	Intentional	x	x
		Unintentional		
		Cannot be controlled		
	Tangibility	Tangible	x	x
		Intangible		
	Transmission modes	Mediated	x	x
		Non-mediated	x	x
Timescales	Target timescale	Very short term		
		Short term	x	
		Medium term	x	x
		Long term		
	Implementation timescale	Pre-operational		x
		Operational	x	x
		Pre-closure	x	x
		Post-closure	x	x
	Development timescale	Done	x	x
		Pre-operational	x	x
		Operational	x	x
		Pre-closure		
		Post-closure		

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

58. The SER concept report includes a study of the Spanish El Cabril disposal facility aimed at informing future SER development processes (see annex to NEA, forthcoming-b).

5.3. **Memory institutions**

Memory institutions such as archives, museums and libraries share the common goal of acquiring, preserving and making information accessible (in the form of records, publications or artefacts) and thus reflect the world's cultural, historic and scientific achievements. They also play an important role in shaping RK&M preservation insights and practices. Therefore, memory institution mechanisms are indispensable components in a systemic RK&M strategy. In some cases, collaboration with a memory institution, such as the national archives, will also be a regulatory requirement for the RWM implementing agency (see below). In general, however, the collaboration and transfer of information material will need to be established as part of an RK&M preservation strategy. The most appropriate institutions for this purpose will need to be selected based on their respective missions and ability to preserve and disseminate information over the considered timescales.

Despite having common goals, archives, museums and libraries differ with regard to their collections as well as to their specific missions, functions, organisation and professional practices. Archives focus on preserving collections of original records that have been selected for permanent or long-term preservation on the grounds of their enduring administrative, informational, cultural, historical or legal value. Archival records are mostly unpublished and almost always unique. A library's main mission is to disseminate various information material to a wide audience. Museums collect and preserve specific artefacts that may or may not be unique or original and present them to the public while providing curatorial context.

Due to technological changes, the formerly sharp distinctions between memory institutions now tend to blur. In a digital environment, the methods of access and presentation allow for linking resources between the different types of collections, which may in turn prove useful in the context of RK&M preservation. Digitisation has the potential to contribute to the decentralisation and democratisation of memory institutions. International archiving initiatives have arisen from this development too and are likely to continue to do so. It must be pointed out, however, that digital information is extremely vulnerable to evolving technology and corresponding preservation strategies must be developed and implemented (see also Section 4.3 on multiple media).

Memory institutions with a different geographical scope of influence (local, regional, national and international) may contribute to RK&M preservation in different ways. National archives, museums and libraries are usually established institutions, responsible for collecting and preserving materials that are relevant and important from a national point of view, which is the case for records and publications related to radioactive waste repositories. Local institutions, on the other hand, are connected to the communities involved in the activities for which RK&M should be preserved. International information resources may also be set up and run by international agencies, on a private or commercial basis, aiming at the permanent preservation of selected record collections of universal value or international scope. At all levels and for all types of memory institutions, international networks are well established today and foster a wide dissemination of information and the use of common standards which, in turn, is beneficial for the accessibility and survivability of the relevant material.

The RK&M initiative dedicated particular attention to national archives (among others by means of a survey of the relationship between RWM organisations and their national archives). Generally, national archives are long-standing institutions that have the institutional responsibility for the "permanent" (i.e. with no time limit) preservation of government or central institutions' records and for providing public access to these records. Since preservation issues are a formalised, key competence of national archives, interaction in the framework of developing an RK&M strategy is thus highly recommendable (and often required by law). In particular, they can be seen as a resource regarding know-how on the proper archiving of records. However, in many countries, national archives are not engaged with national repository projects in a way that is related to the specific needs of RK&M preservation. Two issues in particular came to the fore. The first is whether RK&M preservation needs regarding access can be fulfilled. People not involved in archives may not be aware of their existence, and may find it rather difficult to make sense of the masses of records and the way they are coded and structured. The second is whether the generic selection and preservation standards of national archives are compatible with the RK&M preservation goals of avoiding inadvertent intrusion

and enabling informed decisions. Standard generic archival notions such as "completed process" or "loss of administrative relevance" (both being criteria for the appraisal of archival material prior to its transfer to the archive) should be scrutinised, as they are likely to have a particular meaning for the case of radioactive waste disposal. Moreover, national archives cannot be expected to adapt their (internationally agreed) standards to fulfil RK&M specific needs.

Table 5.2. **Memory institutions: Mechanisms overview table**

Memory institutions					
			Archives	Libraries	Museums
Scope	RK&M type	Information	x	x	x
		Records	x		
		Knowledge		x	
		Memory		x	x
		Awareness			x
	Level of detail	Low level of detail	x	x	x
		High level of detail		x	
	Geographical scope	Local	x	x	x
		Regional	x	x	x
		National	x	x	x
		International			x
		Virtual	x	x	x
Characteristics	Intentionality	Intentional	x	x	x
		Unintentional		x	x
		Cannot be controlled		x	x
	Tangibility	Tangible	x	x	x
		Intangible			
	Transmission modes	Mediated	x	x	x
		Non-mediated	x		
Timescales	Target timescale	Very short term		x	
		Short term		x	x
		Medium term	x	x	x
		Long term	x		
	Implementation timescale	Pre-operational	x		
		Operational	x		
		Pre-closure			
		Post-closure			
	Development timescale	Done	x	x	x
		Pre-operational			
		Operational	x		
		Pre-closure	x		
		Post-closure			

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

Notwithstanding these challenges, the expertise and capacity of national archives with regard to records selection, archival media and accessibility are undoubtedly helpful when developing an RK&M preservation strategy. The establishment of smaller, dedicated archives can also be investigated, such as Nucleus, the Nuclear and Caithness Archives in Wick in the

United Kingdom[59] (see also S. Tucker in NEA, 2013a: pp. 95-97 and 108). As diversity and redundancy are key to any systemic RK&M preservation strategy, it would, in any case, be useful to keep sets of records in several archives at multiple levels. For example, sets of records could be kept in local (municipal) and regional, national, and international archives.

5.4. Markers

Markers are defined as long-lasting objects placed strategically at or near the site for immediate recognition or for discovery at a later time. Within a systemic RK&M strategy, the marker approach is meant to reach out to future generations in the medium to long term. Markers are conceived to be immobile and robust in order to maximise survivability. They should convey messages that are designed to be understandable across generations. Marking can range from a simple stone to a contrived and monumental multi-component system. The RK&M initiative dedicated two studies to the topic: a literature survey (NEA, 2013b) and a case study of the tsunami stones in Japan (NEA, 2014a).

In line with historical markers in other fields (including archaeological artefacts), much attention has been dedicated to large surface markers in the form of monuments. However, a wealth of different ideas, technologies and materials has already been proposed for marking a repository, both on the surface and underground (e.g. berms, magnets, radar reflectors, ceramic tokens, tracers, acoustic signals, etc.) (NEA, 2013b). In addition to deliberately placed markers, the idea of an "archaeology of landscapes" has also been discussed throughout the RK&M initiative (see also A. Storm in NEA, 2015a: pp. 71-73). Residual surface features may occur at disposal sites, such as bund walls built to preserve visual amenity, altered water courses or access routes for road and rail, and these may represent visual clues to previous activity. It has also been suggested that, to a certain degree, repositories mark themselves by means of their content or artificial barrier materials, implying the possibility of a message based on the detection of radioactivity or on other physical properties of disposal components (e.g. gravitational or magnetic anomalies) (see also Setzman, 2014). These elements are, however, not considered to be "markers" in the strict sense as defined in the RK&M glossary set out in Annex 1.

Markers can be conceived as both non-mediated (where the original marker remains) and mediated (where the marker is maintained, repaired or replaced) mechanisms. When conceived as an unmediated mechanism, it is recommended to integrate markers into mediated processes (e.g. in commemorations, cultural heritage schemes and education), thus combining tangible and intangible RK&M preservation components (see also Section 4.3 on multiple media and NEA, 2014a).

Although the placement of markers is typically thought to be a regulatory responsibility of implementing agencies, it is recommended that other actors are involved (e.g. local communities, semioticians and artists) (see also Graham et al., 2018; Thomson and Craighead in NEA, 2015a: pp. 133-135). At present, the use of markers is stipulated in regulation in Switzerland and the United States (see dedicated sections in NEA, forthcoming-a).[60] So far, other countries do not legally require marking repositories for extended periods of time.

59. Nucleus is gradually becoming home to the archives of the entire UK civil nuclear industry, with plans, drawings, photographs, film, microfiche and documents now being stored at Nucleus. Nucleus will also host the archives of the county of Caithness, making historical documents available to members of the public (e.g. for family and local history research). Many staff members were formerly employed by the nuclear sector, and the archive has dedicated attention for public outreach and local added value and participation. See www.highlifehighland.com/nucleus-nuclear-caithness-archives.

60. The Swiss Nuclear Energy Act of 21 March 2003 stipulates that a "repository be durably marked" (see also M. Buser in NEA, 2012: pp. 87-88). The American Code of Federal Regulations on passive institutional controls states that "any compliance application shall include detailed descriptions of the measures that will be employed to preserve knowledge about the location, design and contents of the disposal system. Such measures shall include identification of the controlled area by markers that have been designed and will be fabricated and emplaced to be as permanent as practicable".

Overall, there are currently no straightforward, conclusive answers with regard to the objectives, messages and methods of marking (NEA, 2013b; Pescatore and Schröder, 2014). It is acknowledged that even if markers remain intact and traceable over time, future neglect or misunderstanding of their message cannot be ruled out (e.g. drift in meaning due to cultural and aesthetic interpretations or even the deliberate falsification of messages). The RK&M project supports the idea that markers, if used, should be part of a systemic RK&M strategy aimed at protecting and informing future generations. This firstly means they should not intend to simply scare future generations. Depending on their material, structural design and intended time scope, the information markers are intended to carry can range from "this is man-made" to more elaborate messages. As the example of the pyramids shows, a sheer warning is not enough to keep people away. Warnings are only effective when the addressed share the same symbolic universe of the producers, and even then, men's curious or self-confident nature may supersede. The fear of radiation may become viewed as outdated superstition, just as the fear of the gods did in the case of the pyramids (Wikander, 2015: p. 114). It secondly means that developing an RK&M strategy is never just about placing a marker. Markers should be seen as one component integrated into a broader systemic strategy based on diversity and redundancy. This means they should remain connected to other mechanisms as much as possible.

This was also the lesson learnt from the "tsunami stones" in Japan, which the RK&M initiative studied to examine the role of markers in informing subsequent generations to take appropriate actions against the potential devastation of tsunamis (see A. Van Luik in NEA, 2012: pp. 91-92; A. Van Luik in NEA, 2013a: pp. 77-79; and especially NEA, 2014a). These markers, found primarily on the country's north-eastern shore, were brought to international attention by the 2011 Tōhoku earthquake and tsunami. They commemorate past tsunamis and carry different messages about them, for instance about how to protect oneself by not building houses close to the sea. Figure 5.2 is a picture of a tsunami stone in the village of Aneyoshi. After the village was devastated by a tsunami in 1896, the village was rebuilt in the same place. However, when another tsunami struck in 1933 the village was moved uphill. At that time the tsunami stone in the picture was put in place and is credited with saving the town in 1960 and again in 2011.[61]

Figure 5.2. **Example of a "tsunami stone"**



Note: Built in 1933 below the village of Aneyoshi. It says, "High dwellings are the peace and harmony of our descendants" and "remember the calamity of the great tsunamis. Do not build any homes below this point".

Source: T. Kishimoto.

61. See https://99percentinvisible.org/article/tsunami-stones-ancient-japanese-markers-warn-builders-high-water.

Table 5.3. **Markers: Mechanisms overview table**

Markers							
			Surface markers	Monuments	Sub-surface markers	Deep geological markers	Surface traces
Scope	RK&M type	Information	x	x			
		Records					
		Knowledge					
		Memory		x			
		Awareness	x	x	x	x	x
	Level of detail	Low level of detail	x	x	x	x	x
		High level of detail					
	Geographical scope	Local	x	x	x	x	x
		Regional					x
		National					
		International					
		Virtual					
Characteristics	Intentionality	Intentional	x	x	x	x	x
		Unintentional					x
		Cannot be controlled					x
	Tangibility	Tangible	x	x	x	x	x
		Intangible					
	Transmission modes	Mediated					
		Non-mediated	x	x	x	x	x
Timescales	Target timescale	Very short term					
		Short term					
		Medium term	x	x			
		Long term	x	x	x	x	x
	Implementation timescale	Pre-operational					
		Operational				x	
		Pre-closure	x	x	x	x	x
		Post-closure	x	x	x		x
	Development timescale	Done	x				
		Pre-operational	x	x		x	x
		Operational	x	x	x	x	x
		Pre-closure	x	x	x		x
		Post-closure					

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

Media reports indicated that, in some cases, the local population acted upon the warnings, whereas in many other cases, they were unaware of or ignored them. One of the main lessons from the effective markers was that complementary approaches maintained the interest in and relevance of the stones. In successful cases, markers were notably complemented with forms of intangible cultural heritage and local history (storytelling, commemorations and place names[62]) and education and training (the stones were taught about in school, together with insights about what tsunamis are, their potential effects and which actions one should undertake in case they occur) (see also Section 5.6 on the culture, education and art approach and its respective mechanisms in Annex 2.2). The interplay between the approaches and mechanisms appears to have been one of mutual reinforcement. For example, awareness of the

62. Or "toponyms", such as "Octopus Grounds" and "Valley of Survivors".

markers is passed on from generation to generation through oral history and the presence of markers keeps oral history alive. It was also interesting to learn that after important tsunamis, new stone markers were erected. After the 2011 tsunami, the initiative of creating and installing new stones[63] was led by the Japanese guild of stone masons and not by the authorities. This points out the potential role of civil society organisations in developing and maintaining markers and also, the potential absence of interest by the authorities in this type of approach (NEA, 2014a: p. 8).

5.5. Time capsules

A time capsule is a purpose-built, sealed enclosure, containing a historic cache of information to be used as a means to inform future generations at a specified time or upon accidental discovery. The time capsule concept is workable and ready-to-go, with many examples of implementation and with many documented lessons learnt (see Pescatore and Van Luik, 2016). There also exists an International Time Capsule Society which strives to document all types of time capsules throughout the world.[64]

Time capsules can be seen as a RK&M preservation approach complementary notably to markers and archives, but also to more cultural heritage inspired mechanisms (see Section 5.6). Time capsules can involve a very large array of actors (families, corporations, societies, etc.) and they can contain a large variety of information items (including documents as well as small objects). They can have variable sizes and be placed visibly (e.g. incorporated into a surface marker) or non-visibly (e.g. small time capsules at depth in the vicinity of the repository). They can be designed for opening at an indefinite time upon discovery or at a specific time. In the latter case, openings are often overseen by a group of people and connected to a commemoration or ritual, which creates an additional, intangible form of RK&M preservation.

Some time capsules have planned lifetimes of up to 5 000 years, such as the Osaka Castle time capsule. This is a "dual-time" time capsule. Two identical time capsules were buried in 1970, with the control version designed to be recovered in the year 2000 and every 100 years thereafter.[65] The opening of the control capsule at regular intervals provides the basis for a recurring ritual, as well as the opportunity to apply the most recent preservation techniques for improving the longevity of its content and potentially arresting or reversing degradation.

Time capsules have the potential to preserve records (e.g. the KIF). Additionally, when opened, they may contribute to the regeneration of knowledge (e.g. when interpretable manuals are discovered upon their opening, the content of which can also be refreshed and updated) and memory (by means of carrying contextual information, pictures, newspaper articles, small objects, etc.). They can target the short and medium term, as well as the long term (in which case they may lead to a renewed period of oversight). Also, they can be developed to deploy a mediated or a non-mediated transmission mode, or a combination of both (see the Osaka Castle example above). There is potential for the development of time capsules as a viable approach contributing to an overall RK&M strategy (see also Pescatore and Van Luik, 2016).

One of the projects the RK&M initiative addressed, the Memory of Mankind (MOM), can perhaps be understood as a particular type of time capsule and an illustration of how time capsules could be taken up in a systemic RK&M preservation strategy. It is a preservation project wherein information is printed on ceramic tablets and then stored indefinitely in the salt mine of Hallstatt, Austria. The project includes the ceramic plates that stay in the mine, but every contributing person also gets a duplicate to take home. It also has an online version, meaning that every record is also digitised. Also, every contributor and visitor receives a token with a map indicating the location of the "time capsule". There is a plan for regular 50-year commemorations of the project. Furthermore, it is included in tourist tours due to its vicinity to a UNESCO-listed village. It combines tangible and intangible, and mediated and non-mediated approaches.

63. See e.g. www.tsunami-kioku.jp.
64. https://crypt.oglethorpe.edu/international-time-capsule-society.
65. http://panasonic.net/history/timecapsule.

Table 5.4. **Time capsules: Mechanisms overview table**

Time capsules					
			Large visible time capsules	Large invisible time capsules	Small time capsules
Scope	RK&M type	Information	x	x	x
		Records	x	x	x
		Knowledge			
		Memory			
		Awareness	x		
	Level of detail	Low level of detail			
		High level of detail	x	x	x
	Geographical scope	Local	x	x	x
		Regional	x	x	
		National	x	x	
		International			
		Virtual			
Characteristics	Intentionality	Intentional	x	x	x
		Unintentional			
		Cannot be controlled			
	Tangibility	Tangible	x	x	x
		Intangible			
	Transmission modes	Mediated			
		Non-mediated	x	x	x
Timescales	Target timescale	Very short term			
		Short term			
		Medium term	x	x	x
		Long term	x	x	x
	Implementation timescale	Pre-operational			
		Operational			x
		Pre-closure	x	x	x
		Post-closure	x	x	x
	Development timescale	Done	x	x	
		Pre-operational			x
		Operational	x	x	x
		Pre-closure	x	x	x
		Post-closure			

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

5.6. Culture, education and art

This approach refers to a series of cultural, educational and artistic mechanisms for RK&M preservation. It includes tangible media (such as buildings, man-made landscapes, books and works of visual art[66]) and intangible media (such as commemorations, traditions, teaching and storytelling). The approach notably aims at RK&M preservation for the short and medium term, and the mechanisms mostly deploy mediated transmission modes which include features such as adaptability and flexibility over time. Some mechanisms are proposed to be implemented/located at the site of the waste repository (e.g. alternative reuse of the site or its infrastructure (e.g. hiking/biking trails or an information centre), or maintaining the surface infrastructure as industrial heritage). Others are to be developed and found at various places in society (e.g. literature, art works, education about radioactivity and RWM, and information dissemination activities including exhibitions, documentaries and websites), or combine both

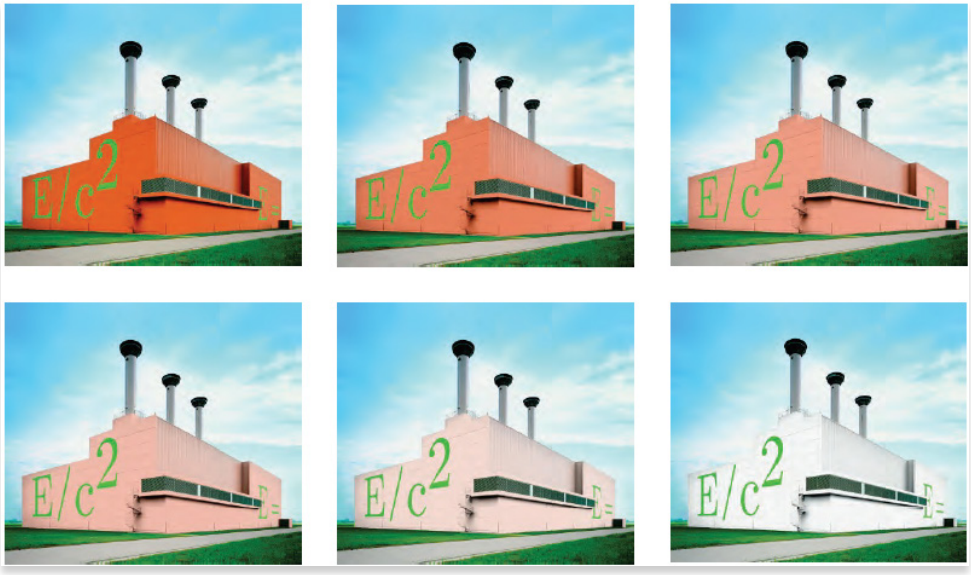
66. The Constructing Memory conference held in 2014 in Verdun had a session dedicated to art as an RK&M preservation mechanism. See NEA, 2015a: pp. 109-135.

on-site and off-site elements (e.g. school visits, research agreements with universities and international commemorations linked to individual facilities). Most mechanisms are directed at or involve a broad range of actors, including local communities, non-governmental organisations, (local) historians, artists, journalists, etc.

It is acknowledged that what may become part of culture or a subject in education and art is not easily pre-defined or controlled. Topics of interest in these fields change over time and are subject to continuous reinterpretation. Nevertheless, they can be powerful frameworks for RK&M preservation as they aim to construct "disposal sites as part of the community, not apart from the community" (NEA, 2015c). The general idea behind the RK&M preservation mechanisms under this approach is to create a long-lasting awareness of and interest in the disposal site with activities that create a type of added value, be it cultural, educational, recreational, aesthetical, intellectual or economic (see also C. Pescatore and C. Mays in NEA, 2013a: pp. 97-103).

As an example, HABOG (Figure 5.3), the high-level waste treatment and storage building at the Central Organisation for Radioactive Waste (COVRA) in the Netherlands, is conceived to change colour from orange in 2003 to white in 2103 as a metaphor for radioactive decay. As such, the surface facility is turned into an art work with features of a marker integrated with other complementary mechanisms such as visiting tours and collaboration with regional museums (H. Codée and E. Verhoef in NEA, 2015a: pp. 53-56).

Figure 5.3. **Example of an artistic approach: "Metamorphosis 2003-2103" by William Verstraeten**



Source: COVRA.

Saint Barbara (Figure 5.4), patron of mining, can be found at many underground research laboratories and disposal facilities today. She has been referred to as a type of "cultural marker".

Nucleus, the nuclear and Caithness archives at Wick, United Kingdom (see Footnote 59), includes an advertisement from 1958 for employment at the nearby Dounreay nuclear facility, a clear example of local history[67] (Figure 5.5). The archive wrote the following about it: "In 1958 we see the Dounreay boom begin to happen with job adverts in many fields. The John O'Groat Journals are a great way to view the rise of Dounreay as they record events as they happen. We

67. "Heimatkunde" in German, "hembygdskunskap" in Swedish.

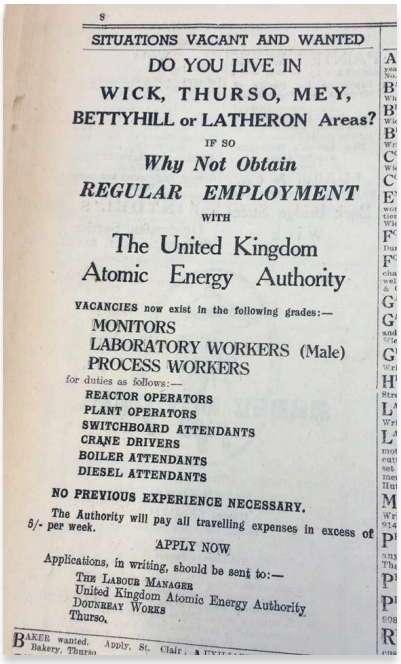
also have a collection of documents relating to Dounreay in this era including [copies of] the Haggis magazine, which were composed by Dounreay workers themselves!".[68]

Figure 5.4. **Example of a "cultural marker": Saint Barbara**



Source: EURIDICE.

Figure 5.5. **Example of local heritage: Dounreay employment advertisement, 1958**



SITUATIONS VACANT AND WANTED

DO YOU LIVE IN
WICK, THURSO, MEY,
BETTYHILL or LATHERON Areas?

IF SO

Why Not Obtain
REGULAR EMPLOYMENT

WITH

The United Kingdom
Atomic Energy Authority

VACANCIES now exist in the following grades:—

MONITORS
LABORATORY WORKERS (Male)
PROCESS WORKERS

for duties as follows:—

REACTOR OPERATORS
PLANT OPERATORS
SWITCHBOARD ATTENDANTS
CRANE DRIVERS
BOILER ATTENDANTS
DIESEL ATTENDANTS

NO PREVIOUS EXPERIENCE NECESSARY.

The Authority will pay all travelling expenses in excess of 5/- per week.

APPLY NOW

Applications, in writing, should be sent to:—

THE LABOUR MANAGER
United Kingdom Atomic Energy Authority
DOUNREAY WORKS
Thurso.

BAKER wanted. Apply, St. Clair, Bakery, Thurso.

Source: Nucleus. The Nuclear and Caithness Archives.

68. Nucleus Nuclear and Caithness Archives Facebook page, www.facebook.com/nucleuscaithnessarchive/photos.

Table 5.5. **Culture, education and art: Mechanisms overview table**

Culture, education and art										
			Industrial heritage	Alternative reuse of the disposal site/ infrastructure	Heritage inventories and catalogues	Local history societies	Intangible cultural heritage	Education, research and training	Public information dissemination activities	Art
Scope	RK&M type	Information			x	x		x		
		Records				x				
		Knowledge						x	x	
		Memory	x	x		x	x			x
		Awareness	x		x		x			x
	Level of detail	Low level of detail	x	x	x	x	x	x	x	x
		High level of detail						x		
	Geographical scope	Local	x	x		x	x		x	
		Regional	x	x	x	x	x	x	x	x
		National			x			x	x	x
		International			x					x
		Virtual			x					x
Characteristics	Intentionality	Intentional	x	x	x	x	x	x	x	x
		Unintentional					x			
		Cannot be controlled	x			x	x			x
	Tangibility	Tangible	x	x	x	x			x	x
		Intangible				x	x	x	x	x
	Transmission modes	Mediated	x	x	x	x	x	x	x	x
		Non-mediated	x							x
Timescales	Target timescale	Very short term						x	x	
		Short term				x		x	x	x
		Medium term	x	x	x	x	x	x		x
		Long term								
	Implementation timescale	Pre-operational				x		x	x	
		Operational			x	x	x	x	x	x
		Pre-closure	x		x	x	x	x		x
		Post-closure	x	x	x		x	x		
	Development timescale	Done	x		x	x		x	x	x
		Pre-operational		x						x
		Operational				x	x			x
		Pre-closure	x	x		x	x			
		Post-closure	x				x			

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

5.7. Knowledge management

Knowledge management is defined as the process of creating, structuring, using, sharing and retaining knowledge held by individuals and organisations in a range of forms or formats. In this context it is necessary to differentiate "knowledge" from "information", "data", "memory" and "records". Knowledge emerges from and accrues in a multi-phase process to create and perform informed decisions and actions, in which an actor understands the consequences. In the context of RWM, knowledge management refers to a mediated, multidisciplinary approach that makes the best use of knowledge across generations, through planned accumulation, sharing and preservation, creating knowledge capacities for as long and for as many stakeholders as possible.

An effective knowledge management strategy typically works with the knowledge owners in a "push-pull" regime. In practice, the "push" phase involves the active management of knowledge, by encoding the knowledge of specialists into a "shared knowledge repository" that can be broadly accessed. The alternative "pull" phase involves "knowledge receivers" making knowledge requests from experts associated with a particular subject or from recorded knowledge previously deposited in an organised manner in the shared knowledge repository.

Knowledge management, including efforts such as on-the-job discussions, discussion fora, corporate libraries, professional training and mentoring programmes, has a long history. However, the discipline and the technology of "knowledge management" has arisen only in the late twentieth century on the basis of the latest information and communication technologies (ICT). With essentially universal access to computer systems, a wide variety of new approaches have been introduced during the last decades, including expert systems, knowledge portals, group decision support systems, collaborative software technologies (ICT-platforms) and artificial intelligence (machine learning) systems. The history of knowledge management as a discipline that uses the latest ICT can be described in four waves:

1. Extraction and preservation of expert knowledge: access to codified knowledge in format of local expert systems (knowledge bases), managed by metadata (since the 1980s).
2. Transfer of best practices: access to cycles of circulation of knowledge in the format of organisational/corporate knowledge management systems with their own applied ontology (since the 1990s).
3. Integrating local expert network systems into "communities of practice" with corporate knowledge management systems: promotion of open innovation, where each user of the product or service can continue to improve it, using his/her access to develop innovative combinations of creation and use of knowledge in multi-agent, ICT based systems (since the 2000s).
4. Building a global architecture for the transfer of knowledge flows including the generation of new knowledge on the basis of global information resources and robotics, including big data, predictive analytics and systems of deep machine learning (since 2010s).

It is clear that this is a rapidly evolving field, which is likely to continue to develop in the future. Artificial intelligence and machine learning may be developed and employed further in the future to allow solutions for intergenerational transmission, inter-cultural translation and inter-organisational knowledge transfers.[69]

For the time being, however, knowledge management notably remains a short-term RK&M preservation mechanism. Commonly used knowledge management processes are fit for building up new knowledge and the maintenance of existent knowledge for time frames that common organisations are used to working with. The RK&M initiative attempted to make a start with addressing the need to consolidate knowledge for reuse across longer time frames with the concepts of KIF and SER (see Section 5.2). Further work still needs to be undertaken on research questions such as: how can current efforts towards the preervation of records, data and metadata (see the RepMet project, www.oecd-nea.org/rwm/igsc/repmet) be broadened to the preservation of knowledge? Also, could the concept of a "knowledge retention plan" (J. Day and E. Kruizinga in NEA, 2013a: pp. 57-61) be further developed to cover the short and the medium term of a repository project?

69. Examples in this direction can be found in the IAEA (e.g. the ICT platform CONNECT), which enables communities of practice to maintain communication and form a network of expertise, and the platform ARTEMIS, which allows IAEA experts to construct models of activities in the areas of RWM, spent nuclear fuel management and decommissioning, and systematise the best practices.

Table 5.6. **Knowledge management: Mechanisms overview table**

Knowledge management					
			Knowledge retention tools	Knowledge risk analysis	Knowledge sharing philosophy
Scope	RK&M type	Information			
		Records			
		Knowledge	x	x	x
		Memory			
		Awareness			
	Level of detail	Low level of detail			
		High level of detail	x	x	x
	Geographical scope	Local	x	x	x
		Regional			
		National			
		International			
		Virtual	x	x	x
Characteristics	Intentionality	Intentional	x	x	x
		Unintentional			
		Cannot be controlled			
	Tangibility	Tangible			
		Intangible	x	x	x
	Transmission modes	Mediated	x	x	x
		Non-mediated			
Timescales	Target timescale	Very short term	x	x	x
		Short term	x	x	x
		Medium term			
		Long term			
	Implementation timescale	Pre-operational	x	x	x
		Operational	x	x	x
		Pre-closure	x	x	x
		Post-closure	x		
	Development timescale	Done	x	x	x
		Pre-operational	x	x	x
		Operational	x	x	x
		Pre-closure			
		Post-closure			

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

5.8. **Oversight provisions**

The concept of "oversight", introduced initially by the R&R project[70] and promoted by the NEA and the ICRP (NEA/ICRP, 2013; ICRP, 2013) has been explained earlier in this report (see Sections 2.1 and 4.2). It remains rather novel, and has not been legally elaborated yet. Rather, it is generically described as "'watchful care' and refers to society 'keeping an eye' on the technical system and the actual implementation of plans and decisions" (ICRP, 2013: p. 20). Therefore, oversight is more process than product focused and as such, a form of mediated transmission of RK&M. Oversight is also described without strictly defined (institutional) responsibilities: "society as a whole" takes part in it, which means it is participatory in nature and requires

70. The NEA Reversibility and Retrievability Project, www.oecd-nea.org/rwm/rr.

ongoing dialogue to periodically renew the basis of understanding among stakeholders (Pescatore et al., 2013; Schröder et al., 2016). While a comprehensive strategy of co-ordinated measures to carry out oversight has not yet been developed, this approach is a first attempt to elaborate some essential oversight mechanisms and to explicate their potential as measures of RK&M preservation.

Oversight and RK&M preservation are not the same, but they work hand in hand (see also S. Hotzel in NEA, 2015a: pp. 65-70). The RK&M initiative adopted the concept of oversight as a key concept for the preservation of RK&M across generations, since RK&M preservation and oversight are mutually reinforcing. Oversight cannot exist without some level of RK&M preservation, and the presence or absence of oversight has an impact on the availability and applicability of RK&M preservation strategies.

Monitoring is probably the most popular and conceptualised oversight provision (see the European project Modern,[71] and also L. Nachmilner, M. Martell, C. Pescatore, C. Mays and M. Jensen in NEA, 2013a: pp. 27-33 and S. Hotzel in NEA, 2015a: pp. 67-68). Monitoring of release pathways and the environment is a clear stakeholder request for both the operational phase (short term) and the post-operational phase (medium term) (NEA, 2014b). Some of the concepts developed for the short term may in fact continue in an adapted form in the medium term (provided the necessary remote technology is available). In recent years, the idea of monitoring non-technical parameters, such as the institutional/administrative provisions or the implementation of measures and agreements has also received increasing attention. RK&M preservation itself can also be monitored. All these activities are part of oversight as they are intended to keep an eye on the technical system itself and on its interaction with the natural and social environment. Implementing agencies, regulators, policy makers, governmental bodies, researchers, environmental groups, local communities and visiting citizens may all be variously engaged in monitoring activities ranging from monitoring of the facility, the environment, the health of surrounding populations, accountability and the legitimacy of land use. The notion of "citizen science" is also interesting in this regard.[72] Citizen science within the nuclear field has received growing attention in the aftermath of the Chernobyl and Fukushima Daiichi accidents, which triggered citizens to start measuring and monitoring radioactivity, often organising themselves in networks that provide platforms for public information and education. Some networks operate locally, but many of these networks are increasingly becoming global in scale (e.g. Safecast[73]). All are formed by volunteers, some collaborate with and are acknowledged by formal institutions while others prefer to remain independent.

Other oversight provisions elaborated as RK&M preservation mechanisms (see Annex 2.2) are "land use controls" and "clear and planned responsibilities". Land use controls are regulatory specifications on how land should (e.g. a nature reserve) and should not (e.g. for tapping thermal resources) be used, including the measures used to implement or enforce these specifications. Clear and planned responsibilities relate to institutional provisions for advance planning, clear assignment and transparent designation of responsibilities for a disposal facility (see also Section 3.3 related to planning of responsibilities). As an oversight provision, this mechanism focuses in particular on the possibly changing or moving responsibilities from an original operator to another competent organisation after closure of the disposal facility. Details of what these responsibilities comprise depend on the disposal facility and national regulation, but they may be generally described as managing and operating the facility before closure, and managing and keeping oversight over the facility after closure.

71. Monitoring Developments for Safe Repository Operation and Staged Closure (Modern), www.modern-fp7.eu and www.modern2020.eu.

72. "Citizen science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources" (EC, 2015).

73. https://blog.safecast.org.

Other oversight measures in the medium term than the three listed above (monitoring, land use controls and clear and planned responsibilities) can also be anticipated. For example, safety reviews and oversight reviews could be carried out on a regular basis. The RK&M preservation mechanisms put forward under the oversight approach are just three examples of relevant oversight provisions for RK&M preservation, not an exhaustive set.

The US DOE Office of Legacy Management[74] (LM) inspired the RK&M preservation approach of oversight provisions. It was established in 2003 to ensure the management of World War II and Cold War legacy sites in the United States after regulatory closure. The office is responsible for fulfilling the Department of Energy's post-closure responsibilities to ensure the future protection of human health and the environment (D. Shafer in NEA, 2013a: pp. 63-65). It offers an example of a systemic RK&M preservation strategy in which oversight provisions are an important approach, combining the following mechanisms:

- A national regulatory framework which specifies the transfer of responsibilities from the licensing body to the oversight body (LM).
- Long-term participatory site management, surveillance and maintenance:
  - e.g. community environmental monitoring programmes and annual maintenance activities.
- Administrative land use control (and the evaluation of its strength, for example by submitting a fake application file for a water well permit).
- Conditional reuse of sites, based on the idea that it is unrealistic to keep people out for the period of time that sites would pose risks and on a change of focus from what *cannot* be done to what *can* be done:
  - recreation, playgrounds and sport pitches, hiking and biking trails, and nature reserves;
  - education agreements with universities:
    - students contribute to DOE studies on landfill evolution over time or conduct environmental research;
  - agriculture:
    - no-cost "leases" for grazing and hay production, where the rancher/farmer serves as local "eyes and ears" for the DOE LM;
  - economic activities:
    - light industry;
    - vehicle storage/parking area;
    - solar energy production systems.

Apart from these oversight mechanisms, LM installs and maintains on-site markers, operates archives to manage records both centrally and locally, and runs public information centres. When possible, LM aims to combine records-related activities with involving multiple stakeholders (particularly at the local level) and routine inspections and monitoring and maintenance activities. Records, knowledge and memory focused components are thus systematically put to work together. Furthermore, information is regularly validated to remain believed, understood and sustained (Idem). Much learning is expected from the workings of LM in the coming years.

74. See https://energy.gov/lm/office-legacy-management.

Table 5.7. **Oversight provisions: Mechanisms overview table**

Oversight provisions					
			Monitoring	Land use control	Clear and planned responsibilities
Scope	RK&M type	Information		x	x
		Records	x		x
		Knowledge	x		x
		Memory	x	x	x
		Awareness		x	
	Level of detail	Low level of detail		x	
		High level of detail	x		x
	Geographical scope	Local	x	x	x
		Regional			x
		National			x
		International			
		Virtual			
Characteristics	Intentionality	Intentional	x	x	x
		Unintentional			
		Cannot be controlled			
	Tangibility	Tangible	x	x	
		Intangible		x	x
	Transmission modes	Mediated	x	x	x
		Non-mediated			
Timescales	Target timescale	Very short term			
		Short term	x		x
		Medium term	x	x	x
		Long term			
	Implementation timescale	Pre-operational	x		x
		Operational	x		x
		Pre-closure	x		x
		Post-closure	x	x	x
	Development timescale	Done			x
		Pre-operational	x	x	x
		Operational	x	x	x
		Pre-closure	x	x	
		Post-closure			

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

5.9. International mechanisms

In view of the fluidity of national boundaries over time and the value of international co-operation in the field of RK&M preservation, both theoretically (by means of insights into their functioning, the peer-reviewed quality standards developed, etc.) as well as practically (by means of real collaboration and real preservation actions), international collaboration received dedicated attention throughout the RK&M initiative (itself an international mechanism dedicated to RK&M preservation) (see also Section 4.7 on locations).[75]

75. Apart from being formulated as a separate approach, potential international dimension was also investigated for all of the 35 mechanisms (see Annex 2.2).

An international mechanism is a mechanism for RK&M preservation that has an international scope, influence or support and is based on international co-operation. An international mechanism can be governmental (based on mutual agreements between a number of national governments) or non-governmental (consisting of entities and activities that bring together non-governmental, private or commercial organisations).

International mechanisms include international regulations and agreements (see also Section 3.3 related to soft law); international standards and guidelines; international inventories and catalogues; international education and training initiatives; as well as international co-operation in a wide sense. These mechanisms may, at different levels and scales, contribute significantly to RK&M preservation in the short and medium term. International heritage inventories may, for instance, record and describe radioactive waste disposal sites. International training initiatives in the nuclear field will contribute to knowledge preservation. Some types of mechanisms will not preserve RK&M directly, but create a favourable framework for RK&M preservation. For example, regulatory instruments at the international level may play a role in increasing the awareness of contracting parties to the issues at stake and in sustaining the common goal identified. Some mechanisms, such as the IAEA Joint Convention, foster periodic reporting. Such reporting, presenting harmonised content in a compact form under the umbrella of an international organisation, contributes to both the development and the preservation of general information on radioactive waste management initiatives in a large number of countries.

Relevant mechanisms may be specific for the nuclear domain, such as the International Nuclear Information System (INIS) of the IAEA (J. Schröder and A. Sneyers in NEA, 2013a: pp. 88-91)[76] and the NEA Data Bank[77] (I. Hill in NEA, 2013a: pp. 91-95). However, instruments in RWM related fields such as geology, spatial development, the protection of the environment or cultural heritage must also be considered. With regard to the latter, UNESCO is well known for its "World Heritage List", which consists of culturally relevant landmarks. However, it also has a programme dedicated to documentary heritage preservation, the Memory of the World programme (MoW) (see J. Springer in NEA, 2013a: pp. 87-88). The three main objectives of the MoW are: i) to facilitate preservation of the world's documentary heritage; ii) to assist public access to documentary heritage (through the use of all media); and iii) to increase awareness of the existence and significance of such heritage. Preservation, access and awareness are also key notions with regard to RK&M preservation related to RWM.

Depending on their specific nature, individual mechanisms may be more or less binding. Some of them may have been incorporated into national legislation or standards and must therefore be implemented, making them mandatory components of a RK&M preservation strategy. In other cases, the link to an international mechanism will need to be actively sought.

Various actors are involved in international mechanisms, ranging from implementing agencies in the case of international co-operation, to commercial enterprises and companies, governments or international organisations in the case of international treaties, standards or training programmes.

Based on a study of several existing international mechanisms (see T. Schneider and C. Reaud in NEA, 2013a: pp. 71-75, and especially NEA, 2015b) important elements in the potential contribution of international mechanisms to RK&M preservation were found to be sustainable funding, a multi-level, multi-stakeholder approach and the voluntary involvement of contracting parties to adhere to a common goal (e.g. societal, environmental or economic).

76. INIS is a bibliographic database and a collection of full-text documents in the broad field of nuclear science and technology, aimed at "organising the world's nuclear information and making it universally accessible" (www.iaea.org/inis).

77. The NEA Data Bank acts as an international centre of reference for basic nuclear tools, such as computer codes and nuclear data, used for the analysis and prediction of phenomena in the nuclear field, and provides a direct service to its users by making such tools available on request and by offering the means and methods needed to support their development, application and validation (www.oecd-nea.org/databank).

Nevertheless, the efficacy of these mechanisms can be limited in case of conflict, which highlights the importance of redundancy in RK&M preservation once more.

Finally, nuclear safeguards was identified as a particular international mechanism which deserves further attention with regard to their interface with RK&M preservation (see also the next section on the regulatory framework).

Table 5.8. **International mechanisms: Mechanisms overview table**

			International mechanisms					
			International regulations and agreements	International standards and guidelines	International inventories and catalogues	International co-operation	International education and training programmes	International archiving initiatives
Scope	RK&M type	Information	x	x	x	x		x
		Records	x	x				x
		Knowledge		x		x	x	
		Memory						
		Awareness	x		x			
	Level of detail	Low level of detail	x	x	x			
		High level of detail	x	x	x	x	x	x
	Geographical scope	Local						
		Regional						
		National						
		International	x	x	x	x	x	x
		Virtual			x			x
Characteristics	Intentionality	Intentional	x	x	x	x	x	x
		Unintentional						
		Cannot be controlled						
	Tangibility	Tangible	x	x	x			x
		Intangible	x	x		x	x	
	Transmission modes	Mediated	x	x	x	x	x	x
		Non-mediated						x
Timescales	Target timescale	Very short term		x		x	x	
		Short term	x	x	x	x	x	
		Medium term	x	x	x	x		x
		Long term						x
	Implementation timescale	Pre-operational	x	x	x	x	x	
		Operational	x	x	x	x	x	
		Pre-closure	x	x		x	x	x
		Post-closure	x	x		x		x
	Development timescale	Done	x	x	x	x	x	
		Pre-operational			x	x		
		Operational	x	x	x	x		x
		Pre-closure				x		x
		Post-closure						x

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

5.10. Regulatory framework

As discussed in Section 3.3, RK&M preservation is a dynamic, diverse and context-dependent issue that does not easily lend itself to being translated into tight rules. Nevertheless, a regulatory framework is a necessary approach within a systemic RK&M preservation strategy. RK&M preservation does not "happen by itself"; RK&M loss does. National regulation should equip actors with concepts and guidelines that are clear enough, not only to initiate action and planning today and over time, but also to enable compliance review and enforcement mechanisms. It is hoped that the findings and the proposed mechanisms of the RK&M initiative can offer inspiration in this regard.

A national regulatory framework can, at minimum, include guidelines related to archiving records. The preservation of knowledge and memory are more difficult to regulate directly, but are just as important. Therefore, a national regulatory framework would also include the preparation and implementation of RK&M preservation mechanisms complementary to archiving, such as developing a key information file (KIF), land use control, monitoring, information dissemination activities, markers, etc. The regulatory framework can thus stipulate RK&M products as well as processes. By applying life cycle thinking, RK&M preservation regulation should go beyond short-term, operational requirements alone and proactively focus on the period after closure too. While developing this mechanism and controlling its efficacy is a key responsibility of national nuclear regulators, other regulatory fields, actors and levels (local, regional and international) are also involved. It also needs to be noted that regulation relevant to RK&M preservation comes from multiple sources and relates to multiple fields (not only the nuclear field and regulator), including environmental protection, spatial planning, safety, security, heritage preservation and archiving. A national regulatory framework should moreover be in line with international regulations, but adapted to the national context.

Nuclear safeguards were identified as a particular mechanism that may contribute to a systemic RK&M preservation strategy. Safeguards are the institutional controls to verify compliance with the international treaty on the non-proliferation of nuclear weapons (NPT) and, where relevant, the European Euratom treaty. In the context of disposal of radioactive waste, safeguard measures refer to having clear information about the fissile material content of the repository, verifying this information over time and monitoring the disposal sites with the aim of making sure that no malevolent use of the technology or material occurs. There is no specific time limit concerning how long safeguard measures should continue. Previous IAEA guidance states that the termination of safeguards will be determined based on when the nuclear material subject to safeguards has been consumed, diluted, or has become practicably irrecoverable (IAEA, 1972). The current IAEA guidance related to geological disposal states that safeguards will continue after repository closure. The safeguards principles applied during the operational phase would continue after closure for as long as the repository remains under safeguards, i.e. for as long as the NPT is in force (IAEA, 2010).

Safeguards address only a subset of RK&M preservation. They only focus on fissile material and on human intrusion, not on supporting informed decision making about repositories and their content in general; perhaps quite the contrary. Because of its security-related nature, the information collected under safeguards agreements is generally kept confidential. Nevertheless, it is an established international regulatory mechanism that includes activities that overlap with RK&M preservation, such as record keeping, record verification over time and knowledge transfer. Above all, regulatory guidance and supervision should support a systemic approach to RK&M preservation, as will be further explained in the next chapter.

Table 5.9. **Regulatory framework: Mechanisms overview table**

Regulatory framework				
			National regulatory framework	Safeguards
Scope	RK&M type	Information	x	x
		Records	x	x
		Knowledge	x	x
		Memory	x	
		Awareness	x	
	Level of detail	Low level of detail		
		High level of detail	x	x
	Geographical scope	Local		
		Regional		
		National	x	x
		International		x
		Virtual		
Characteristics	Intentionality	Intentional	x	x
		Unintentional		
		Cannot be controlled		
	Tangibility	Tangible	x	x
		Intangible	x	x
	Transmission modes	Mediated	x	x
		Non-mediated		
Timescales	Target timescale	Very short term		
		Short term	x	x
		Medium term	x	x
		Long term		
	Implementation timescale	Pre-operational	x	x
		Operational	x	x
		Pre-closure	x	x
		Post-closure	x	x
	Development timescale	Done		
		Pre-operational	x	x
		Operational	x	
		Pre-closure	x	
		Post-closure		

Note: This table shows the mechanisms – with a profile of their key characteristics – that belong to the RK&M preservation approach presented in this section. The full descriptions of the individual mechanisms follow, in a comprehensive, structured and standardised format, in Annex 2.2. The rows in this table are derived from those description sheets. For a full explanation of the descriptors, please see Annex 2.1.

5.11. References

EC (2015), "White Paper on Citizen Science", www.socientize.eu/sites/default/files/white-paper_0.pdf.

Graham, N. et al. (2018), "Nuclear, landmarker for a waste isolation site: International architecture competition", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

IAEA (2010), *Technological Implications of International Safeguards for Geological Disposal of Spent Fuel and Radioactive Waste*, NW-T-1.21. IAEA, Vienna.

IAEA (1972), *The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-proliferation of Nuclear Weapons*, INFCIRC/153, IAEA, Vienna.

ICRP (2013), *Radiological Protection in Geological Disposal of Long-Lived Solid Radioactive Waste*, ICRP Publication 122, Annals of the ICRP, Vol. 42/3, pp. 1-57.

NEA (forthcoming-a), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Catalogue of Legislation, Regulation and Guidance Governing the Preservation of RK&M for Radioactive Waste Repositories*, OECD, Paris.

NEA (forthcoming-b), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Compiling a Set of Essential Records for a Radioactive Waste Repository*, OECD, Paris.

NEA (2019), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Developing a Key Information File for a Radioactive Waste Repository*, OECD, Paris.

NEA (2015a), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate,* OECD, Paris, www.oecd-nea.org/rwm/pubs/2015/7259-constructing-memory-2015.pdf.

NEA (2015b), "International Mechanisms to Support Records, Knowledge and Memory Preservation Over the Short and Medium Term", NEA/RWM/R(2015)2, www.oecd-nea.org/rwm/docs/2015/rwm-r2015-2.pdf.

NEA (2015c), *Fostering a Durable Relationship between a Waste Management Facility and its Host Community: Adding Value through Design and Process – 2015 Edition*, OECD, Paris.

NEA (2014a), "Markers – Reflections on Intergenerational Warnings in the Form of Japanese Tsunami Stones", NEA/RWM/R(2014)4, www.oecd-nea.org/rwm/docs/2014/rwm-r2014-4.pdf.

NEA (2014b), "Preservation of Records, Knowledge and Memory across Generations (RK&M). Monitoring of Geological Disposal Facilities – Technical and Societal Aspects", NEA/RWM/R(2014)2, www.oecd-nea.org/rwm/docs/2014/rwm-r2014-2.pdf.

NEA (2013a), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding", www.oecd-nea.org/rwm/reports/2013/rwm-r2013-3.pdf.

NEA (2013b), "A Literature Survey on Markers and Memory Preservation for Deep Geological Repositories", www.oecd-nea.org/rwm/docs/2013/rwm-r2013-5.pdf.

NEA (2012), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue: Workshop proceedings", www.oecd-nea.org/rwm/docs/2012/rwm_r_2012_6.pdf.

NEA (2010), "2010 Survey on Long-term Preservation of Information and Memory for Geological Disposal of Radioactive Waste", NEA/RWM(2010)7/REV.

NEA/ICRP (2013), "Radiological Protection and Geological Disposal: The Guiding Principles and Recommendations of the International Commission on Radiological Protection (ICRP)", www.oecd-nea.org/rwm/documents/icrp-rp-gd.pdf.

Pescatore, C. and A. Van Luik (2016), "Millennial Time Capsules as a Promising Means for Preserving Records for Future Generations", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

Pescatore, C. and J. Schröder (2014), "Markers and Deep Geological Repositories – Learning within the OECD/NEA Project on the Preservation of Records, Knowledge and Memory across Generations", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

Pescatore, C. et al. (2013), "Oversight of a Deep Geological Repository and the Role of Monitoring – Some preliminary findings within the RK&M Project of the NEA", paper presented at the MoDeRn International Conference, 19-21 March 2013, Luxembourg.

Schröder, J., N. Rossignol and M. Van Oudheusden (2016), "Safety in long term radioactive waste management: Insight and oversight", *Safety Science,* Vol. 85, pp. 258-265, www.sciencedirect.com/science/article/pii/S0925753516000382.

Setzman, E. (2014), "Preservation of Information and Communication With Future Generations", paper presented at the Waste Management Conference, Phoenix, Arizona, United States.

Wikander, O. (2015), "Don't push this button: Phoenician sarcophagi, "atomic priesthoods" and nuclear waste", *Vetenskapssocieteten i Lund. Årsbok 2015*, Rahm, H. Lund, Vetenskapssocieteten, Lund.

Chapter 6. Towards a systemic strategy for RK&M preservation

The RK&M initiative emphasises the importance of utilising multiple mechanisms. Even if they are presented positively a single approach, let alone a single mechanism, has little chance to effectively preserve RK&M across generations. With a view to maximising information accessibility, understandability and survivability over the timescales considered, a systemic RK&M preservation strategy should be adopted.

6.1. Creating diversity and inter-connectedness among RK&M preservation system components

A systemic RK&M preservation strategy refers to a network of various RK&M preservation approaches and mechanisms that:

A. Have different characteristics (see Chapter 4):
   - taking into account multiple time frames (short, medium and long term);
   - using multiple media (both tangible and intangible, oral and written, multi-language, textual and visual, etc.);
   - having multiple contents (more technical, more contextual, high and low levels of detail, etc.);
   - deploying multiple transmission modes (mediated and non-mediated, and taking into account both continuity and discontinuity in the functioning of society over time);
   - involving and addressing multiple actors;
   - covering multiple locations and scopes.
B. Are integrated with one another or complement one another, act as indexes to each other, and provide for redundancy.

The combination of RK&M preservation approaches and mechanisms should be chosen on the basis that it optimises the RK&M preservation system's robustness and resilience through: A) diversity (implementing various approaches with multiple mechanisms with different characteristics); and B) inter-connectedness (integration, complementarity, cross-referencing and redundancy among the mechanisms of the various approaches). The inter-connectedness between different mechanisms within the developed system can take a variety of forms, ranging between:

- redundant/independent;
- linking/complementary;
- indexing/supporting;
- integrating/reinforcing.[78]

78. While contradictory information is to be avoided, it may also push RK&M preservation if it causes debate, communication and interest, and encourages people to look for more information to find out which source is right. For example, reading that the siting of the repository was a democratic decision in the KIF while local history reveals it was contested may lead to the tracing back of older records, the (re-)activation of storytelling, etc. Also, for example, differing monitoring results from activities by different actors may lead to further research, checking archived records, renewed monitoring schemes (perhaps with international collaboration).

Mechanisms that aim at preserving awareness and that bear information in a rather low level of detail (e.g. markers, some art works, etc.) are especially recommended to be strongly interconnected with more detailed information aimed at the preservation of memory and knowledge (e.g. the KIF, information centres, monitoring programmes, archives, etc.). While redundancy means that some elements of the systemic strategy can be degraded or lost without substantial damage to its overall RK&M preservation capacity (Trauth et al., 1993: p. F-33), overall, a systemic strategy entails that the "components relate to one another in such a way that the whole is more than the sum of its parts" (Trauth et al., 1993: p. F-11). In addition to storing the same records in several archives or several artefacts in the same location, more wide spread redundancy and variation makes duplicated information more reliable and varied information more interesting (C. Holtorf in NEA, 2013: pp. 48-50).

To aid RK&M preservation actors, the mechanism description sheets developed by the RK&M initiative (Annex 2.1) display diversity (the tick boxes under the key characteristics fields, also visualised in an overview table in Annex 2.3) and include a dedicated field to indicate connections to other approaches/mechanisms.

The remainder of this section points out other key issues, next to the diversity and interconnectedness of its components, to be taken into consideration when developing and implementing a systemic RK&M preservation strategy.

6.2. Meeting national needs

The proposed "toolbox" of approaches (Chapter 5) and their mechanisms (described individually in Annex 2.2, with an overview table in Annex 2.3) are meant to allow stakeholders to identify elements of a strategic action plan for RK&M preservation. Such an action plan may become an important management tool in the disposal process that national institutional actors will need to develop at one time or another. The RK&M initiative's idea behind the "menu" or "toolbox" of specific mechanisms grouped into overarching approaches, is that they can be selected, adapted and combined to suit the needs of individual national programmes.

For any disposal facility, the chosen strategy for RK&M preservation, as well as its specific implementation, will be context dependent and remain a national[79] decision. Besides, each repository requires a unique RK&M preservation strategy (see also Section 4.7). The RK&M initiative's presentation of approaches and mechanisms is believed to benefit individual programmes by providing a shared, broad-based and documented understanding regarding methods, concepts and activities on preserving RK&M across generations. Such an understanding (regulatory, technical, managerial, institutional, societal and culture-specific) can be used as a reference for all stakeholders involved in RWM in general and RK&M preservation in particular. It is meant to foster the development of scientifically underpinned and societally responsive strategies and regulations for individual RWM programmes. Additionally, the proposed approaches and mechanisms may offer a platform for innovative forms of engagement and mutual learning among various disciplines and societal actors, especially because they are not meant to be exhaustive or prescriptive, but inspirational and adaptable to context-dependent variables. All the uses outlined can be elaborated regardless of the stage of repository development.

6.3. RK&M preservation starts today – life cycle thinking

While the focus is on preserving RK&M for the post-closure repository phase, the RK&M initiative emphasises that RK&M preservation starts today and needs to be acted upon in the decades leading up to repository closure, when the interest level is high and funding is available. Information that will form part of RK&M preservation across generations will be acquired from the early days of disposal projects onwards.

79. Or multinational needs, should multinational disposal programmes be implemented in the future.

The underlying idea is also that in making information more transparent, more visible and more widely known in society today, we can have a greater chance that information will be transmitted into the future via "societal" or "collective" memory. This refers back to the concurrent review and communication function of RK&M preservation mentioned earlier, valid for the present as well as the future (Section 2.1 on the connection to safety).

The focus of RK&M preservation is on the future, but concurrently on the present ("what can we do today"). Although the implementation of RK&M preservation measures will be a rather minor item in the overall costs of building and operating a repository, "the practical present" also includes the discussion and preparation of sources and uses of funds (see also Section 3.4).

Developing and implementing a systemic RK&M preservation strategy also implies life cycle thinking, in which, as explained earlier:

a) All the sub-processes of the information life cycle (production, preservation and access) are taken into account (see Section 3.1) and connections between the preservation of records, knowledge and memory are made, highlighting that records will not only be used by their original makers, and should be developed and preserved in such a way that future actors can use and make sense of them (see also Section 4.3).

b) Connections between the pre-operational, operational and post-operational phases of repository projects are made, highlighting that RK&M preservation, its regulation and its funding should go beyond short-term operational requirements alone and proactively focus on the period after closure (see Sections 4.2 and 5.10).

6.4. **RK&M preservation is an ongoing process**

While life cycle thinking is encouraged in RK&M preservation, it also needs to be acknowledged that in reality, the cycle cannot be closed today. The success of RK&M preservation cannot be judged by whether RK&M will last for thousands of years. This remains impossible to predict or demonstrate. It can only be evaluated in an ongoing manner, as it depends on whether or not it establishes the relevance and responsibility in the minds and attitudes of waste producers, regulators, implementing agencies, other stakeholders and the general public today, and whether that need and responsibility is understood and passed on to the next generation (NEA, 2013: p. 108). This also more generally implies that RK&M preservation strategies will need to be flexible and adaptable over time.

To a certain degree, this is already exemplified in RWM guidelines today, especially for the short term (see Section 4.2), by the description of the disposal implementation process as a stepwise, iterative process organised to enable flexibility, adaptability and learning (both techno-scientifically as societally) (NEA, 2004). Such a process *requires* RK&M preservation and it also *enables* it, as it implies deliberating earlier decisions before proceeding to next steps and also recording these deliberations and decisions. The length of the operational phase also creates an opportunity for the reflective development and adaptation of workable RK&M strategies in this regard (NEA, 2014). However, RK&M preservation will always remain an ongoing task, also beyond the short term. And it may develop quite differently over time than foreseen today (mechanisms may be initiated but later abandoned, funding may be withdrawn, etc.).

While it is important to start the implementation of various RK&M measures at an early date and to have a clear goal in view, one needs to bear in mind that this plan will undoubtedly need to be adjusted over the course of time. There is no absolute standard for the implementation of RK&M measures. Therefore, it is considered to be good practice to foresee multidisciplinary and participatory reviews at various points in the process (see also Section 6.5). This would allow other perspectives to be introduced and identify any gradual drift away from the desired intent. Since the topic of RK&M preservation so unmistakably requires and involves a variety of insights and actors at the production, preservation, as well as the access level (see Section 3.1), it may even be understood as a platform for innovative forms of engagement and mutual learning over time.

6.5. RK&M preservation is a participatory process

Inter- and trans-disciplinarity (see Section 4.6) are crucial when designing, developing and implementing a systemic RK&M preservation strategy, both with regard to its content and its methods. A participatory process is believed to support diversity and redundancy by eliciting various perspectives on how the fundamental objectives of protecting humans and the environment and supporting informed decision making can best be translated, and by enabling RK&M to be carried by as many and various actors as possible. This has an ethical grounding related to intra- and intergenerational justice (see also Chapter 2 and Section 3.4), but is also supported by substantive arguments.

A first substantive argument for developing and implementing RK&M preservation as a participatory process is that the more people know about and are involved with RWM in general and disposal projects in particular, the higher the chances are that RK&M preservation and oversight will be developed and maintained. This contains an element of redundancy; if one actor fails, others can still continue. But participation also creates an opportunity for the respective actors to add value to RK&M preservation, which will add to its endurance (see also NEA, 2015b). Information can be useful beyond its original purpose. For example, data about the tides used to be collected by fishermen, but also became useful for specific sports and today proves useful for climate scientists. The more people have use for data, the more people will invest in its preservation.

Secondly, in order to preserve RK&M in a manner that optimally serves the aims of protecting and informing over time, it is recommendable that those who are addressed are also involved to the highest degree possible. The time gap between the producer and the receiver cannot be addressed directly, but a multidisciplinary and participatory process can at least serve as an access "pilot test" in the present. It is, for instance, recommendable to have actors such as communication specialists, teachers and non-professional locals involved in the preparation of documents for a wide audience, "to avoid (nuclear) specialist jargon and actively pursue the language of daily life" (E. Van Hove in NEA, 2015a: p. 106; see also NEA, 2019).

In light of the extended time frames of RWM, a third pragmatic function of developing and implementing RK&M preservation in a participatory manner, as discussed in the section on planning responsibilities (Section 3.3), is that responsibilities for RK&M preservation and oversight are most likely to change over time, and one should not expect actors that were never involved in RWM to suddenly take over and feel responsible. Early involvement beyond the currently responsible RWM actors is therefore recommended.

6.6. Illustration: Two fictional examples

This section offers two fictional examples of what an RK&M preservation strategy could look like. They are meant to illustrate the possible use of the "toolbox" of approaches and mechanisms, keeping in mind the earlier guidelines for developing a systemic strategy. Acknowledging the relatively early stage of conceptual planning for RK&M preservation and the context-dependency of any actual RK&M strategy, these examples should by no means be understood as a rigid recipe for developing and implementing a RK&M preservation strategy. They serve to outline what a systemic strategy could look like in practice, and, in line with the entire report, are meant to initiate reflection and to illustrate and inspire, rather than to determine and prescribe.

For the examples, the following classification has been made among the proposed approaches and mechanisms:

- Compliance activities: needed to comply with the international and national regulatory framework. Any RK&M system that does not comply with these legal requirements is likely to be judged to be incomplete or non-compliant.
- Best practice activities: which can be regarded as "core mechanisms" and should therefore attract priority funding.
- Supporting activities: to optimally reach diversity and inter-connectedness among approaches and mechanisms, and to optimally support contextual adaptability.

Fictional example 1

Compliance activities

This fictional example is steered by the assumption of a directive national regulatory framework for RK&M preservation, requiring the use of archives, land use controls and the installation of visible markers by law. The RK&M preservation mechanisms implemented for this repository focused on ensuring that the archiving process and associated physical record store were ready and that land use controls were in force. For the design and installation of a marker system, external experts were hired by the implementing agency and were completed under contract.

Best practice activities

The RK&M preservation strategy development was driven by the implementing agency, as an additional task for the largely technical staff. The implementing agency developed a KIF because the local government requested it. It was stored in a paper and a digital version at the city hall. The implementing agency put a lot of time and effort into the development of the SER, also because a divergence was discovered rather late in the process between the internal archiving standards and those of the national archive. This caused some budgetary issues and even some turmoil in the regional press. The concerns about the lack of transparency related to the records turned into concerns related to long-term health effects. Action groups pleaded for the retrieval of the waste and the closure of the repository. Following these events, the regulator and the government organised information dissemination activities in the region and the local government organised a multidisciplinary process to revise the KIF (involving the facility implementer, communication specialists and representatives of a newly established local stakeholder group). In its new form, the KIF was distributed to the nearest schools and libraries, which also received some additional information materials on radioactivity and RWM in general from the implementing agency. The preservation of the installed markers was taken up by the national guild of masons, which developed an interest in repository markers worldwide.

Supporting activities

The implementing agency recognised the importance of an active knowledge management process for the short term within the organisation. A commitment was made to participate in an international Community of Practice on this issue. After the local schools received the KIF, information sessions were organised by some teachers for parents. Some parents showed an interest in site visits and contacted former staff of the implementing agency. The land controls, however, prevented such visits.

Fictional example 2

Compliance activities

The national regulatory framework for this disposal project only prescribed the "making of provisions for long-term record preservation". "The preservation of knowledge and memory about the facility" was, however, requested by the host community, which had become engaged in the disposal project through the siting process. The implementing agency complied with the law by means of compiling a SER (supported by international collaboration) and worked together with the national and local archives. Furthermore, an ongoing review and implementation of any laws and binding international agreements was instituted and regularly refreshed through a peer review process.

Best practice activities

The implementing agency made a commitment to organise and maintain an interdisciplinary process for RK&M strategy development, including researchers from the natural, material, and social sciences and humanities. This was done in full collaboration with the host community, who among others decided upon the prioritisation of RK&M mechanisms. The host community was also engaged in the preparation, maintenance and distribution of a KIF for the facility.

Similarly, efforts were made to select and maintain the records to make up the SER with the drivers for records retention being agreed with the host community. In collaboration with the national and local governments and in interaction with two universities, post-closure oversight provisions, including monitoring, were also agreed upon.

Supporting activities

The implementing agency worked proactively with the host community and other interested parties nationwide via various media to plan and organise other RK&M tools according to prioritisation and affordability. This resulted in new opportunities for education in nuclear science and related topics through the funding of RK&M related research and studentships. It also resulted in registration with several international mechanisms, including both inter-governmental and privately-run memory initiatives, as well as national mechanisms, such as the national inventory of industrial heritage. The implementing agency also maintained an accessible website (among others with 3D visualisations) and interacted with the national media to inform the broader public.

The potential for cultural activities was recognised through a national call for artists for the design of markers (with funding through a "percent for art" scheme) and the establishment of a visitor centre in the host municipality, including displays that combined the emergence of the repository within the "local history". Beneficial reuses of the site were discussed with broad stakeholder involvement, including the implementing and regulatory agencies, the local and regional government, and local representatives from economic, nature and recreational interest groups. A local contest was organised to come up with new street names that relate to the existence of the facility and maps were adapted accordingly. A ritual related to monitoring was developed, which drew attention from a variety of actors from different research fields.

The implementing agency and host community also spent some time examining the potential benefits of time capsules and sub-surface markers and built up a fund over some years to implement them as closure approached. With the help of specialists, they continued to be active in the review and development of active knowledge management processes well beyond formal closure of the facility.

6.7. **References**

NEA (2019), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Developing a Key Information File for a Radioactive Waste Repository*, OECD, Paris.

NEA (2015a), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate,* OECD, Paris, www.oecd-nea.org/rwm/pubs/2015/7259-constructing-memory-2015.pdf.

NEA (2015b), *Fostering a Durable Relationship between a Waste Management Facility and its Host Community. Adding Value through Design and Process – 2015 Edition*, OECD, Paris.

NEA (2014), "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 (RWMC)", www.oecd-nea.org/rwm/rkm/documents/flyer-A4-rkm-collective-statement-en-2014.pdf.

NEA (2013), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding", www.oecd-nea.org/rwm/reports/2013/rwm-r2013-3.pdf.

NEA (2004), *Stepwise Approach to Decision Making for Long-term Radioactive Waste Management. Experience, Issues and Guiding Principles*, OECD, Paris.

Trauth, K.M., S.C. Hora and R.V. Guzowski (1993), *Expert Judgement on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant,* SAND92-1382 l UC-721, prepared by Sandia National Laboratories for the US Department of Energy, Albuquerque, New Mexico and Livermore.

Chapter 7. **Conclusions and outlook**

7.1. **Conclusions**

Many countries today are engaged in the development of projects for the final disposal of radioactive waste. Disposal facilities will be developed, implemented and operated over many decades and are meant to remain functional for up to hundreds of thousands of years in the case of high-level radioactive waste and spent fuel.

Embedding disposal facilities in society

In the past, the vision seems to have been that radioactive waste management (RWM) ended with, or at least shortly after, the closure of a disposal site. Oversight after closure was not an issue that was studied, developers tacitly assuming the safe oblivion of repositories, or that markers would succeed in deterring intrusion into a repository (see Section 1.2). Today, it is recognised that disposal facilities will remain part of society over time and that scaring people off or encouraging oblivion are not viable strategies. Future generations should be able to keep oversight over disposal sites for as long as they want, and this requires the preparation of a variety of instruments today, including records, knowledge and memory (RK&M) preservation (see Section 2.1). As the International Commission on Radiological Protection puts it: "one of the important factors that influence the application of the protection system over the different phases in the life time of a disposal facility is the level of oversight or 'watchful care' that is present. […] The level of oversight directly affects the capability to reduce or avoid some exposures" (ICRP, 2013: pp. 34-35). The RK&M initiative highlighted and elaborated that such a vision shift with regard to the future requires an accompanying shift with regard to present thinking and practices.

Preventing inadvertent human intrusion and supporting informed decision making over time

RK&M loss has indeed been found to take place rapidly if it is not acted upon in a dedicated manner and embedded in a regulatory framework (see Chapter 3). In the context of hazardous waste management, overall it was learnt that, even in the short term, bad quality or lack of RK&M jeopardises informed decision making and can present the involved parties with significant impacts on project schedules and costs, and increased health and safety risks. RK&M preservation thus constitutes a dedicated management task in RWM that is best started by the generations responsible for producing the waste, while waste management plans are being designed and implemented and while interest is present and funding is available (see Sections 3.4 and 6.3).

Addressing the question of "Why should we try to continue to remember and understand across generations where, why and how radioactive waste is disposed?" on a more fundamental level, RK&M preservation aims to avoid inadvertent human intrusion into a repository and to enable future generations to make informed decisions about the repository (see Chapter 2). Addressing these objectives can only be done in a manner that combines records, knowledge and memory preservation. It is not only about keeping information as such, but about preserving selected data and information that has been committed to a medium and accompanied by the appropriate context and structure for later uses (records). Moreover, records in themselves have limited meaning without the ability to understand and utilise the data and information they carry (knowledge). In order for this combination of records and knowledge to be transferred across generations, in whatever form and detail, there needs to be

awareness of their existence and the reason for their existence, which is supported by a broader awareness of events, people, places and levels of knowledge in the past (memory).

RK&M preservation thus goes well beyond present data management and record keeping alone. It is not just a question of handing down a message, but of keeping that message interpretable, meaningful, credible and usable over time. Put more generally, RK&M aims at keeping track of disposal projects across time, by supporting an informed and alert attitude towards the required levels of safety, security and societal accordance, not only by the implementing agency and the authorities, but also by society at large and local communities in particular. As such, RK&M preservation concurrently has a communication and an evaluation function. These functions do not change over time and are valid for the present as well as the future, for both the operational and the post-operational phases of disposal facilities. Against this background, RK&M preservation has been identified as an integral part of responsible RWM, in line with a prudent approach to safety and a conscious attitude to ethics.

Based on these more theoretical understandings, elaborated throughout the first part of this report (see Chapters 1-3), the RK&M initiative also formulated more practice-oriented recommendations, elaborated throughout the second part of this report (see Chapters 4-6).

Developing a systemic strategy for RK&M preservation

A fundamental recommendation of the RK&M initiative is to develop a systemic strategy for RK&M preservation. This recommendation is based on the finding that there is no single approach or mechanism that would achieve, on its own, the preservation of RK&M over centuries and millennia. To state it bluntly, simply putting up a marker or placing records in an archive will not achieve the desired result. RK&M preservation requires a well-considered combination of different RK&M preservation approaches with multiple mechanisms. The desired diversity can be achieved by combining approaches and mechanisms that vary among the following key characteristics set out in Chapter 4:

- addressed time frame (short, medium and long term);
- type of medium (tangible/intangible, oral/written, multi-language, textual/visual, etc.);
- type of content (more technical, more contextual, high/low levels of detail, etc.);
- mode of transmission (mediated/non-mediated, taking into account both continuity and discontinuity in the functioning of society over time);
- involved and addressed actors;
- implied locations and scopes.

The RK&M initiative developed a non-exhaustive “toolbox” of 35 concrete RK&M preservation mechanisms that differ with regard to the key characteristics just mentioned. They can be adapted and combined to achieve a context-responsive, individual systemic RK&M preservation strategy with optimal diversity (see Annex 2). The mechanisms themselves are, with a few exceptions, not new. On the contrary, to the degree possible they are hinged upon structures and interests that already exist in society. What is original is how to use and apply them within a systemic RWM related RK&M preservation strategy. The proposed mechanisms are classified under nine overarching RK&M preservation approaches set out in Chapter 5, namely:

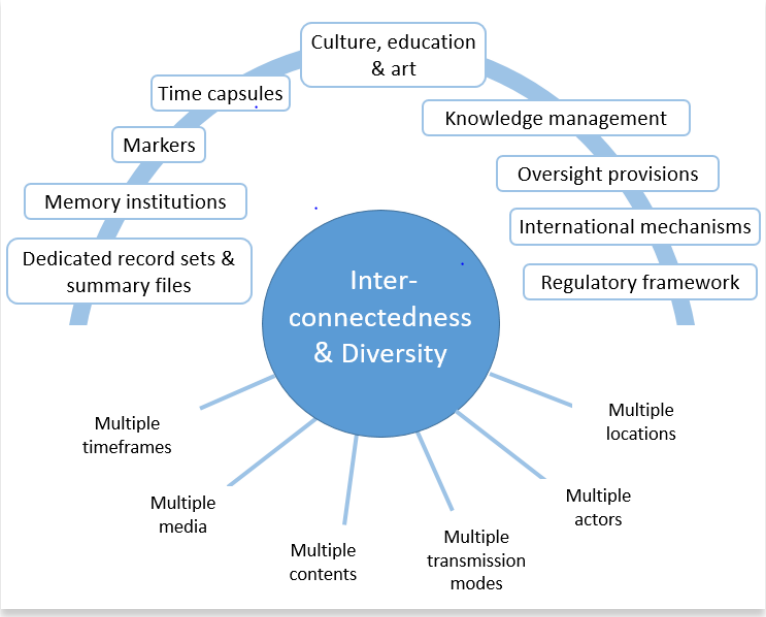
- dedicated record sets and summary files (the set of essential records and the key information file);
- memory institutions (archives, libraries and museums);
- markers (both above and below the surface);
- time capsules (both with and without opening strategies);
- culture, education and art (industrial heritage, cultural heritage, education and research, works of art);

- knowledge management (knowledge retention tools, knowledge sharing philosophy);
- oversight provisions (monitoring, clear and planned responsibilities, land use controls);
- international mechanisms (international regulations and agreements, international inventories and catalogues);
- regulatory framework (encompassing the national regulatory framework and safeguards).

When combining these approaches and their mechanisms, particular care should be dedicated not only to their diversity but also to their inter-connectedness. The components of a systemic RK&M preservation strategy should work together, complement and strengthen each other, act as indexes to each other and thus provide diversity and redundancy with a view to maximising information accessibility, understandability and survivability over the various timescales considered.

Figure 7.1 visualises the concept of a systemic strategy, by illustrating the promoted diversity (lower part of the figure) and the inter-connectedness between the different RK&M preservation approaches and their underlying mechanisms (upper part of the figure).

Figure 7.1. **A systemic strategy: Creating diversity and inter-connectedness among different RK&M preservation approaches and their underlying mechanisms**



The importance of multi-disciplinarity and participation

RK&M preservation inherently requires to be elaborated as a multidisciplinary and participatory process (see Sections 4.6 and 6.5). To address the fundamental objectives of avoiding inadvertent intrusion and supporting informed decision making over time, RK&M preservation aims at the societal embedding of the repository by creating a holistic disposal project in which the disposal technology, the site's design and the societal environment are integrated and mutually supporting. This can only be achieved through an effort that combines the workings and insights from the spheres of institutional, professional, academic and daily life. Since the topic of RK&M preservation so unmistakably requires and involves a variety of insights and actors at the production, preservation, as well as the access level (see Section 3.1), it may also offer a platform for innovative forms of engagement and mutual learning.

This also means that RK&M preservation is not only about products (e.g. a record, an archive, a marker), but as much about (ongoing) processes (recording, knowing, memorising, preserving, learning, involving, sharing, etc.). Overall, RK&M preservation requires forward looking, life cycle thinking as set out in Section 6.3, but also a stepwise methodology, characterised by flexibility and adaptability over time (see Section 6.4). The success of RK&M preservation cannot be judged today by whether they will last for one thousand or ten thousand years. It can only be evaluated in an ongoing manner, as it depends on whether or not it establishes the relevance and responsibility in the minds and attitudes of waste producers, regulators, implementing agencies, other stakeholders and the general public today, and whether that need and responsibility is understood and passed on to the next generation.

7.2. Outlook

Upholding and elaborating an open and holistic attitude

The RK&M initiative has broken new ground in long-term RWM, going beyond the technical aspects of nuclear technology development, encouraging a holistic approach towards RWM and highlighting it as a societal and intergenerational endeavour. The aim of the initiative was not to create ready-made products or recipes for RK&M preservation, but to encourage reflection, to inspire, to involve and to create societal awareness. This had the additional benefit of starting to create and transfer RK&M today, both tangible (reports and papers, a website, etc.) and intangible (a network, spreading an interest, etc.).

By forming a multidisciplinary group and by reaching out to specialists that are not typically represented in RWM organisations, the initiative made a start with involving and engaging new groups of people in the field of nuclear waste disposal and RK&M preservation, and with building bridges between disciplines that otherwise rarely collaborate. This inter-disciplinarity helped to address and develop RK&M preservation as a task in which technical, scientific, societal and cultural information is interwoven, and where a variety of both more technical and more social methods should be assessed and deployed. Apart from formulating firm recommendations to develop and implement a systemic RK&M preservation strategy, the topic of RK&M preservation also served as a vehicle to discuss varying opinions and values in RWM more broadly, and to do so in a constructive and inspiring way. This included reflections on fundamental topics such as knowledge building, dealing with uncertainties, science communication, the interaction between society and technology, and intergenerational ethics.

Creating awareness, supporting engagement and starting RK&M preservation today

Against this background the RK&M initiative envisions the future of the work to be performed in this field, within the NEA and beyond, as consisting of two prominent, overlapping action items. Firstly, to uphold and elaborate the open and reflexive attitude within the field of RWM related RK&M preservation, which entails further learning and elaborating interaction with multiple disciplines and civil society actors. Secondly, to start assembling the components of a real RK&M approach, for example – by testing the recommendations formulated throughout this report in practice. In sum, the RK&M initiative's outlook consists of:

- further learning related to currently underdeveloped items (e.g. related to costs and funding and to extended knowledge preservation strategies);
- consolidating and embedding lessons learnt (e.g. related to the development of a SER);
- reaching out to different communities (e.g. organising a participatory process for the preparation and management of a KIF).

Broadly disseminating the results of the RK&M initiative can be seen as a first, specific action item. Taking into account the breadth of the audience described in Section 1.1, distributing this report and other deliverables to as many potentially interested stakeholders as possible, inside and outside the nuclear domain, is only a starting point. With a view to starting systemic RK&M preservation as a dedicated management task sooner rather than later, several

opportunities for developing RK&M preservation mechanisms in a multidisciplinary and participatory manner have been indicated throughout this report, including:

- proactive and systematic record management for the development of a SER;
- compiling a preliminary KIF working with, among others, communication specialists and local community representatives;
- reviewing the national regulatory framework with a view to closing gaps, in particular with respect to clear and planned responsibilities;
- pilot design of markers as a collaborative RD&D activity;
- preparatory discussions related to alternative land use with local and regional actors;
- exploring collaborations with the national archive;
- preparation of information packages and interactions with schools;
- interactions with universities.

Together with the main chapters in this report the tools in Annex 2 (the mechanism description sheets and overview table), are designed to provide hands-on guidance for the development and implementation of real, practical systemic RK&M preservation strategies. First and foremost, as a result of the RK&M initiative it is hoped that various actors will actually start working with these insights and tools and will find them helpful. It should be noted that various mechanisms may already exist today, albeit not as dedicated radioactive waste disposal-related RK&M preservation mechanisms. Tracking such initiatives and, where possible and useful, liaising with those belonging to approaches that are not primarily developed by the implementer (e.g. higher education or heritage inventories) is also a specific action item.

Developing international collaboration

The national level, in collaboration with the local and regional levels, will play a prominent role in developing and carrying out RK&M preservation activities. This is where the cornerstones of a systemic strategy should be discussed and defined, taking account of the national and local context and national and international agreements. However, activities can also be addressed internationally, for example via the Forum on Stakeholder Confidence (FSC), which constitutes the core of such expertise at the NEA. Overall, the fact that the initiative took place under the aegis of an international agency, such as the NEA, has already yielded benefits for sharing issues, learning together and harmonising approaches between national programmes.

The continuation of an "international RK&M preservation network" is thus recommended, as an interactive platform to continue to develop ideas, establish collaborations, and share findings related to putting lessons learnt into practice (e.g. exchanging experiences with visitor centres, participatory monitoring initiatives, partnerships with archives). In line with the growing attention for human aspects of nuclear safety,[80] issues such as the role of RK&M preservation within the safety case may also be discussed internationally, for instance within the framework of the NEA Integration Group for the Safety Case (IGSC) and the Regulators' Forum (RWMC RF). Through the RK&M initiative the NEA has already established connections with UNESCO to jointly discuss potential collaborations in the field of RK&M preservation (e.g. related to nominating NEA reports for the Memory of the World programme). These and other international collaborations, both inside and outside the nuclear domain, are expected to have the potential to substantially contribute to RK&M preservation. This would be particularly relevant when designed to support cross-fertilisation between different administrative and geographic levels, different disciplines and domains and different stakeholders.

7.3. **Reference**

ICRP (2013), *Radiological Protection in Geological Disposal of Long-Lived Solid Radioactive Waste*, ICRP Publication 122, Annals of the ICRP, Vol. 42/3, pp. 1-57.

80. See also www.oecd-nea.org/hans.

Annex 1. **RK&M glossary**

The RK&M glossary represents a peer-reviewed set of terms and their definitions, serving the purpose of efficient communication and better understanding of RK&M preservation issues within and beyond the NEA RK&M initiative. It defines the most important key terms and concepts used in the project and as such provides useful guidance on terminology in the area of RK&M preservation for radioactive waste disposal, including the pre- and, especially, post-closure phases of repositories. The terms and concepts in the glossary do not uniquely pertain to the RK&M preservation topic. They are also used in other contexts and international texts, where their meaning may differ. The RK&M project glossary definitions do not necessarily reflect the most common understanding or use of the terms. The definitions provided aim at stipulating the respective term within the RK&M preservation context.

The glossary was developed and updated iteratively throughout the duration of the RK&M initiative by its members. The guiding principles in preparing glossary entries were: i) usefulness within the wider RK&M preservation context, ii) understandability, iii) internal consistency with respect to other glossary entries, and iv) unambiguousness.

Archive

Collection of records that have been selected for permanent preservation due to their continuing administrative, informational, legal and historical value as evidence of the work of the creating organisation or programme. The term "archive" also refers to the building or part of a building in which archives are preserved and made available for consultation, as well as to the agency or programme responsible for selecting, acquiring, preserving and making available archives.

Commentary: National archives acquire, preserve and make available for research national records, in particular those created by national agencies. They usually establish policies and procedures for managing these records and assist national agencies in carrying out their record management responsibilities.

Archives differ from libraries in the sense that libraries are usually created with the intention of providing public access to collections of published materials.

Archives differ from time capsules in that they are maintained to preserve, and to provide the means to access, their inventories.

Awareness

Consciousness of the existence of something.

Commentary: "Something" can refer to a tangible object ("awareness of the repository", "awareness of the records") or to an intangible object ("awareness of a problem", "awareness of events in the past").

Control

The function of directing, ruling, regulating, restraining or limiting.

Commentary: Control can be carried out by individuals, groups of individuals, institutions and inanimate objects. These are referred to as "controllers".

Control implies not only checking or monitoring something but also ensuring that corrective or enforcement measures will be taken if necessary.

Control is about influencing people or (features of) a technical system.

The transitive verb "to control someone/something" is used with the meaning of "to exercise control over someone/something".

Care should be taken not to confuse the following: (A) control as a function (i.e. the function of controlling), (B) the controller (i.e. the subject/object that exerts control), (C) the means of control (i.e. the device or resource that the controller employs to exert control). While all three can be, and have occasionally been, termed "control" in the past, this glossary definition applies to (A) only. For instance, markers and archives do not perform control functions; therefore they are not "controls".

Composite expressions

Institutional control: Control by an authority or institution.

Regulatory control: Short for "control by the national nuclear safety authority". Institutional control is broader than, and includes, the regulatory control by the national nuclear safety authority. Various forms of additional institutional control will take place in parallel to regulatory controls sensu stricto, such as controls by advisory bodies to parliament, by environmental courts and bodies, by other regulators – local and national – than those in charge of nuclear safety, e.g. the occupational safety regulator, the mining safety regulator, by local committees legally entitled to carry out forms of controls. Additional institutional controls may also take place to fulfil international agreements, e.g. on safeguards.

Built-in control, or intrinsic control: Control that is exerted by components of the system itself (e.g. buffer, barriers) over technical features of the system such as the influx of groundwater, the temperature of the near field, the release of radionuclides, etc. The concept of "built-in controls" constitutes a cornerstone in the ICRP-122 reference terminology. It complements the concept of "oversight", which is a function carried out by people, with a control function carried out by system components.

Cultural heritage

Cultural heritage refers to physical artefacts and intangible attributes that society identifies and values for reasons beyond mere utility, as a reflection and expression of its knowledge, beliefs, traditions and the ways of living it has developed.

Commentary: Heritage is our legacy from the past, what we live with today and what we pass on to future generations. According to the "Heritage Cycle", heritage has to be understood in order to be appreciated and valued. By valuing it, people will want to care for it. This will result in enjoying it and wanting to understand more, thus closing the loop and beginning a new cycle.

Heritage encompasses, broadly, the natural environment (such as habitats, species, ecosystems, geology and landforms to which people attach value), the built environment (such as buildings and monuments, townscapes, archaeological sites) and artefacts (such as books and documents, objects, works of art). Cultural heritage also includes intangible human artefacts (such as folklore, traditions, language).

Data

Facts and ideas in the form originally collected.

Information

Organised data that may or may not be recorded on a medium.

Commentary: With this definition, the creation of information (e.g. by organising data) requires human activity, but the preservation of information does not. For example, a marker preserves information, independently of the presence of intermediaries.

Knowledge

The result of learning processes. Once acquired in a particular field, knowledge provides insights and skills. It results in the ability to understand, interpret and use the relevant data, information and records.

Composite expressions

Knowledge preservation: Preservation of knowledge, in a particular field is about maintaining or creating learning processes in that field. An example over the medium term would be the funding of a university chair; another example over the medium term would be facilitating the passing of skills from one generation to another.

Knowledge reconstruction: Over the long term, knowledge will inevitably be diluted as interest fades. Tools/opportunities then need to be devised for knowledge reconstruction. For instance, the Rosetta Stone proved to be a vital tool for reconstructing the knowledge of the ancient Egyptian language.

Regaining knowledge: Since media that are meant to support knowledge (e.g. books, records, instructions) are not understood as "knowledge" in this report (no matter whether they have been written with the intention to codify somebody's knowledge therein) the term "knowledge preservation" is not used to describe the process of record preservation. However, preservation of records may be understood as preserving the possibility to *regain* knowledge (through studying the preserved media).

Long term

This term refers to the period of time in the post-operational repository phase when oversight has been lost. The long term extends over the whole period over which, according to the safety regulations, safety must be demonstrated, typically hundreds of thousands of years in the case of high-level waste. (See also "short term", "medium term" and "oversight".)

Marker

A long-lasting object that indicates an area of influence, power or danger. It is placed strategically at or near the site for immediate recognition or for discovery at a later time.

Commentary: A marker is an object meant to reach out to future generations in the medium to long term. Any marker is conceived to be immobile (i.e. in permanent association with a site), robust, in order to maximise survivability on its own, and to provide messages designed to be understandable across generations.

Mediated/non-mediated transmission

Mediated transmission: The message or record is passed on from one generation to another.

Non-mediated transmission: The message or record is sent directly (and in its original format) from the present time to the future receiver.

Commentary: In mediated transmission, each generation may undertake steps that affect the continuity of readability (legibility and language) and understandability (comprehension and context). Non-mediated transmission places no reliance on the presence of intermediaries. It is recognised that these two "tracks" of transmission may address different target audiences, convey different levels of detail and use different technical means to achieve survivability.

Medium term

This term refers to the period of time of indirect oversight activities that would follow repository closure. Timescales are typically in the order of a few hundred years. (See also "short term", "long term" and "oversight".)

Memory

The awareness of events, people, places and levels of knowledge in the past.

Message

A significant point that is conveyed in concise form.

Monument

A visible and complex type of marker, i.e., a large building or an ensemble of structures. A monument may consist of several visible and less visible markers, e.g. in order to encircle an area. Like a marker, a monument may bear a message, e.g. in the form of inscriptions, or be the message itself. (See also "marker".)

Oversight

"Oversight is a general term for 'watchful care' and refers to society 'keeping an eye' on the technical system and the actual implementation of plans and decisions." (ICRP, 2013)

Commentary: Oversight is the reference concept promoted by the ICRP for reconciling geological disposal with fundamental principles of radiological protection (see Section 2.1 for details).

Record

A usually unique and original object or a selected piece of data/information that has been committed to a medium (analogue or digital) and that is kept, together with the appropriate context and structure, for later use.

Commentary: In the vast majority of cases, records will be documents. But also other original objects can be considered records. Generally, records should be pieces of evidence of (past) activities. Another aspect to distinguish records from other objects is that records should be, in principle, suitable for archiving, so that markers, monuments, etc. are not regarded as records. Usually, records are the entity of the medium and the information on it (e.g. a folder, a CD). In case of electronic files, however, one may still consider them "records" even if there is no original "medium" (e.g. if stored in a IT "cloud").

Redundancy

In the context of a RK&M preservation strategy, "redundancy" means that some elements of the strategy can be degraded or lost without substantial damage to its overall RK&M preservation capacity (based on Trauth et al., 1993: p. F-33).

Short term

This term refers to the period of time that ends with repository closure. This period includes both the pre-operational and the operational phases of the repository. Timescales are in the order of 100 years. (See also "very short term", "medium term" and "long term".)

Stakeholder

Any actor (institution, group or individual) with an interest, concern or role to play in the radioactive waste management related RK&M preservation process.

Systemic strategy

An RK&M preservation strategy whose components offer a variety of RK&M transmission mechanisms that are integrated with one another or that complement one another, act as indexes to each other, and provide for diversity and redundancy, with a view to maximising information accessibility, understandability and survivability over the timescales considered.

Commentary: A dual-track strategy – providing mechanisms for both mediated and non-mediated transmission of information – is part of a systemic strategy.

Very short term

A period of time consistent with staff stability in role, cycles of organisational change and regulatory expectations of periodic safety reviews. Typical timescales are 10 to 20 years. (See also "short term".)

References

ICRP (2013), *Radiological Protection in Geological Disposal of Long-Lived Solid Radioactive Waste*, ICRP Publication 122, Annals of the ICRP, Vol. 42/3, pp. 1-57.

Trauth, K.M., S.C. Hora and R.V. Guzowski (1993), *Expert Judgement on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant*, SAND92-1382 l UC-721, prepared by Sandia National Laboratories for the US Department of Energy, Albuquerque, New Mexico and Livermore.

Annex 2. **Descriptions of RK&M preservation mechanisms**

The RK&M initiative elaborated 9 approaches containing 35 mechanisms of RK&M preservation. The overarching approaches are described in Chapter 5 of the main body of this report. This annex presents the individual mechanisms in a comprehensive, structured and standardised format, which allows for their comparison and combination (Annex 2.2).

The mechanisms themselves are – with a few exceptions – not new. What is original, is how to use and apply them within a systemic RK&M preservation strategy. This is explained in the standard template used for presenting them (Annex 2.1), which highlights the diversity of the various mechanisms (see Chapter 4 of the main body of this report which explains the variety among the key characteristics) and visualised by a practical overview table (Annex 2.3).[81]

2.1. **Mechanism description sheet: template**

The first part of this annex contains an empty mechanism description sheet, a template with instruction indicators. It helps to understand the filled out templates in the next section (Annex 2.2) and may be put to use should actors wish to develop their own, new mechanisms. It covers the following areas:

- a definition/description of the mechanism;
- how it contributes to RK&M preservation;
- its key characteristics (tick boxes connect to Section 4 of the report);
- main strengths and benefits/specific issues and challenges;
- international dimension;
- links to other mechanisms;
- references for further reading and examples.

<table>
<tr><th>Mechanism</th><th colspan="5">Name of the mechanism</th></tr>
<tr><td>Approach</td><td colspan="5">Name of the approach the mechanism belongs to.</td></tr>
<tr><td>Definition/description</td><td colspan="5">Definition from the RK&M glossary if available. Otherwise, provide a brief, new description.</td></tr>
<tr><td>How does this mechanism contribute to RK&M preservation?
How can it be implemented?</td><td colspan="5">Describe the link between this mechanism and RK&M preservation. How does it work? How it is intended to reach future generations? How can the process be influenced so that the mechanism will play a meaningful role in RK&M preservation?</td></tr>
<tr><td rowspan="10">Scope
(Tick appropriate box[es] using an “X”. Write a short explanation in the field for comments. More than one tick is possible. Less than one tick is also possible if none of the choices fit [which can also be explained in the field for comments]. Use “NA” if the question is not applicable [and explain this in the field for comments].)</td><td colspan="5">Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?</td></tr>
<tr><td>Information: X</td><td>Records:</td><td>Knowledge:</td><td>Memory:</td><td>Awareness:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
<tr><td colspan="5">What is the level of detail addressed/provided by the mechanism?</td></tr>
<tr><td colspan="3">Low level of detail: X</td><td colspan="2">High level of detail:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
<tr><td colspan="5">What is the main geographical or administrative-political scope (development/implementation /operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field “International dimension” further below.]</td></tr>
<tr><td>Local: X</td><td>Regional:</td><td>National:</td><td>International:</td><td>Virtual:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
</table>

81. All web links included in Annex 2 tables were accessed in 2018.

<table>
<tr><th>Mechanism</th><th colspan="5">Name of the mechanism</th></tr>
<tr><td rowspan="11">Timescales
[Tick appropriate box(es) using an “X”. Write a short explanation in the field for comments. More than one tick is possible. Less than one tick is also possible if none of the choices fit (which can also be explained in the field for comments). Use “NA” if the question is not applicable (and explain this in the field for comments).]</td><td colspan="5">Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term: X</td><td>Medium term:</td><td>Short term:</td><td colspan="2">Very short term:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
<tr><td colspan="5">When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational: X</td><td>Operational:</td><td>Pre-closure:</td><td colspan="2">Post-closure:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
<tr><td colspan="5">When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: X</td><td>Pre-operational:</td><td>Operational:</td><td>Pre-closure:</td><td>Post-closure:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
<tr><td rowspan="11">Characteristics
[Tick appropriate box(es) using an “X”. Write a short explanation in the field for comments. More than one tick is possible. Less than one tick is also possible if none of the choices fit (which can also be explained in the field for comments). Use “NA” if the question is not applicable (and explain this in the field for comments).]</td><td colspan="5">Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td>Intentional: X</td><td>Unintentional:</td><td colspan="3">Cannot be controlled:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
<tr><td colspan="5">Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td>Tangible: X</td><td colspan="4">Intangible:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
<tr><td colspan="5">Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td colspan="2">Mediated transmission: X</td><td colspan="3">Non-mediated transmission:</td></tr>
<tr><td colspan="5">Comments:</td></tr>
<tr><td>Actors</td><td colspan="5">Indicate which actors/organisation is expected to be responsible for the decision/development/implementation of the mechanism.
E.g.: the implementing agency will probably carry responsibility for preparing the SER, while a government agency is likely to be responsible for installing land use restrictions.
In some cases, it can be useful to distinguish between the body that makes the actual decision and/or develops the mechanism, and the organisation that implements it (e.g. norms and standards are developed by national and international bodies, but the responsibility for implementing them lies with individual organisations).
Apart from the formally responsible actors, try to also indicate which actors are likely to/should best be involved in the planning, development and implementation process (e.g. local communities, interest groups, specialists in a particular field).</td></tr>
<tr><td>Main strengths/benefits</td><td colspan="5">What are the specific advantages of this mechanism? Why should it be implemented?</td></tr>
<tr><td>Specific issues/challenges</td><td colspan="5">Have issues/challenges been identified or can they be foreseen (e.g. understandability of symbols for markers, loss of meaning over time, issues of funding)?</td></tr>
<tr><td>International dimension</td><td colspan="5">If applicable, describe the (potential) international relevance/dimension of this mechanism.</td></tr>
<tr><td>Connection to other approaches/ mechanisms</td><td colspan="5">Point to other mechanisms that may be related, e.g. through their scope or the way they work (e.g. “international treaties, conventions and directives” can be linked to “national legal framework”; “land use control” can be linked to “alternative reuse of the site and/or its infrastructure”).
If not self-explanatory, connections such as redundancy, complementarity, indexing, etc., between the mechanisms may be briefly explained here.</td></tr>
<tr><td>Information resources issued by the RK&M initiative</td><td colspan="5">Documents produced in the framework of the RK&M project, if any (workshop/conference proceedings, project studies, project reports, papers).</td></tr>
<tr><td>Other information resources</td><td colspan="5">References to most recent sources of information, especially if the RK&M initiative has not published a study on the subject.</td></tr>
<tr><td>Examples</td><td colspan="5">List of meaningful, specific examples, preferably in various countries, with a link to electronic resources if available and a short explanation if necessary.</td></tr>
</table>

2.2. Mechanism description sheets

This section presents the 35 mechanism description sheets as filled out by the RK&M group members. The mechanisms are meant to be inspirational and adaptable to context-dependent variables, rather than exhaustive or prescriptive. It should be noted that the references and examples given are only meant as orientations and illustrations. They reflect the current knowledge of the group members and are not meant to be (internationally) exhaustive.

Dedicated record sets and summary files

Key information file (KIF)

<table>
<tr><th>Mechanism</th><th>Key information file (KIF)</th></tr>
<tr><td>Approach</td><td>Dedicated record sets and summary files</td></tr>
<tr><td>Definition/description</td><td>The KIF is conceptualised as a single, short document that provides a summary of location, content and intent of a disposal facility. It is intended to provide an overview of the disposal project in a concise form, and should be as widely distributed and accessible as possible. The information it contains should be sufficient to allow society to know about the repository and to reduce the likelihood of uninformed human intrusion.</td></tr>
<tr><td>How does this mechanism contribute to RK&M preservation/ How can it be implemented?</td><td>A KIF would be a single document, produced in a multidisciplinary and participatory manner, intended to inform present and future people without specialised knowledge. Such a file would be widely distributed in many copies (e.g. at the disposal site, in the town hall, in libraries, on websites of international agencies, in schools). It is meant to provide an overview of the disposal project in a concise form, containing basic information on the repository and the waste it contains, as well as a summarised history of decision making.
The KIF is a summary document. It must point to mechanisms that preserve more detailed information (among others the SER) about the disposal facility, its content and associated safety cases. Ideally, features of the document structure would be harmonised for different KIFs pertaining to various repositories around the world.</td></tr>
<tr><td rowspan="10">Scope</td><td>Does the mechanism mainly preserve information, records, knowledge, memory or awareness?</td></tr>
<tr><td>Information: X | Records: X | Knowledge: | Memory: X | Awareness:</td></tr>
<tr><td>The KIF contains information about the repository, which, indirectly, fosters the memory, and to a lesser degree awareness and basic knowledge of the repository. The participatory process that underpins the KIF concept (during the mediated transmission phase of the KIF) adds to the preservation of memory. The KIF can be considered as a record in itself.</td></tr>
<tr><td>What is the level of detail addressed/provided by the mechanism?</td></tr>
<tr><td>Low level of detail: X | High level of detail:</td></tr>
<tr><td>The KIF will preserve information about the repository with a relatively low level of detail (in comparison to e.g. the SER), but with a sufficiently high level of detail for its readers to understand the existence and intent of a repository.</td></tr>
<tr><td>What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation?
[Note also the field “International dimension” further below.]</td></tr>
<tr><td>Local: X | Regional: X | National: X | International: X | Virtual:</td></tr>
<tr><td>The KIF has a wide geographical scope. The target audience is notably the local, regional and national level, although it also has an international scope, in view of the intended international accordance with regard to its format and contents, and its multilingual chapters. It may be distributed and used online/virtually.</td></tr>
<tr><td rowspan="6">Timescales</td><td>Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term: | Medium term: X | Short term: X | Very short term:</td></tr>
<tr><td>The KIF is intended to develop accessible information for as many people as possible and to preserve it for as long as possible, at least during the period of oversight. Its influence may extend into the long term. It can also be relevant for the very short term, as a means to start RK&M preservation via dialogue (how to “tell the story” of the repository).</td></tr>
<tr><td>When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational: | Operational: X | Pre-closure: X | Post-closure: X</td></tr>
<tr><td>The KIF can be prepared from the early days of repository development, to fully exploit its potential as a tool for communication and dialogue. The compilation process may continue throughout the operational phase. It can be completed at closure, or it can be maintained throughout the post-closure phase.</td></tr>
</table>

Mechanism	Key information file (KIF)				
Timescales.	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational: **X**	Operational: **X**	Pre-closure:	Post-closure:
	The concept of a KIF has been developed by the RK&M initiative (NEA, 2019). National programmes can work with this concept to develop it further according to the national situation.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	The KIF needs to be developed, maintained and preserved intentionally.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	The KIF is a tangible document. The process leading up to the KIF (dialogue, discussion, summarising, interpreting, updating, etc.) can be seen as an intangible RK&M preservation element of the KIF.				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission: **X**	Non-mediated transmission: **X**			
	Both mechanisms are possible for the KIF, but it is anticipated that versions of the KIF would periodically be renewed and that it is actively transferred from one generation to the next, improving accessibility and endurance by allowing for updates with regard to content (e.g. wording, language, insights) and carriers.				
Actors	The preparation of the KIF could be the responsibility of the implementing agency, but the involvement of multiple disciplines (including e.g. communication specialists) and stakeholders (e.g. local community and government, teachers) is highly recommended. Since the KIF should be widely distributed and preserved, here too multiple actors will be involved, including e.g. local and national archives, local museums, local heritage actors, and school libraries.				
Main strengths/benefits	The KIF is designed to be short and easy to read, and produced in a participatory and harmonised style. It may be copied onto various carriers, including long-lasting media. The KIF can be easily networked into an overall RK&M preservation strategy. Copies of the KIF may e.g. be included in time capsules, parts of it may be copied onto site markers, and it can be used for a large variety of dissemination activities, in education, for site visits, or to inform alternative land uses. It can also point to KIFs of other repositories, and to more detailed documents (e.g. the SER).				
Specific issues/challenges	Writing a KIF will be an enriching but also a challenging experience – the right experts (drawn from both techno-scientific and socio-scientific backgrounds) should be involved in the process. Various versions of the KIF may be distributed simultaneously for a given repository. This is because it may be updated (e.g. due to changes in the repository, safety case reviews, etc.) and is widely distributed at each stage. Care should be taken to provide only the information that is necessary to inform society and to avoid inadvertent intrusion. Security issues may limit the information that may be disclosed on other repositories.				
International dimension	International harmonisation with regard to the generic content and outline of the KIF is recommended.				
Connection to other approaches/ mechanisms	Dedicated repository records and summary files: SER *(the KIF and the SER should point to each other)* Culture, education and art (*the KIF can inform/be included in all mechanisms under this approach)* Time capsules *(the KIF may be included in them)* Memory institutions *(the KIF can be kept in archives and libraries)* Regulatory framework (*a KIF may be required by the national regulatory framework)* Oversight activities *(KIF content and revision can be coupled to oversight activities)*				
Information resources issued by the RK&M initiative	NEA (2019), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Developing a Key Information File for a Radioactive Waste Repository*, OECD, Paris.				
Other information resources	Dumont, J.-N. et al. (2016), "Key Information File for Radioactive Waste Repositories – Preliminary Tests", Waste Management Conference WM2016, Phoenix, Arizona, United States.				
Examples	Example KIFs are being produced for the following three facilities: WIPP (DOE, United States), DGR project (SKB, Sweden), La Manche surface repository (Andra, France). A summary of these example KIFs is presented in the appendix to the KIF concept report (NEA, 2019).				

Set of essential records (SER)

Mechanism	Set of essential records (SER)				
Approach	Dedicated record sets and summary files				
Definition/description	A SER has been defined as "A collection of vital records selected for permanent preservation during a repository project lifetime, aimed at providing sufficient information for current and future generations to adequately understand the repository system, to enable them to review and verify the repository performance and the safety case, in order to make informed decisions about it."				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	The SER provides detailed information on the repository system, primarily for decision makers and professionals. It can be implemented as soon as a site is selected, by identifying and compiling the records deemed relevant for long-term preservation. It needs to be regularly reviewed during the operational phase. Some additional records from the post-closure surveillance period should consequently be added to it. The SER will be issued in at least two copies, one being transferred to the national archives. An electronic SER database is recommended for the SER's operational use.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory or awareness?				
	Information: **X**	Records: **X**	Knowledge:	Memory:	Awareness:
	The SER, consisting of a selection of relevant records, should serve as a source of detailed data and information on the repository system aimed to make informed decisions. The records would allow future populations to regain knowledge if required.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail:			High level of detail: **X**	
	The SER is meant to preserve a considerable amount of detailed information about the repository.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional: **X**	National: **X**	International:	Virtual:
	The SER has wide geographical and administrative scope, extending from local to national. In the short term, an electronic/virtual SER database may be possible, but the maintenance of such a database over the target timeframes of the SER could be challenging.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term:	Very short term:	
	The SER is intended to provide information for many hundreds of years. It could also prevent the loss of records in the short term.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure: **X**	
	The SER compilation starts as soon as a site is selected and continues before, during and after the operation of the facility.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational: **X**	Operational: **X**	Pre-closure:	Post-closure:
	The concept of a SER has been developed by the RK&M initiative (NEA, forthcoming). National programmes can work with this concept to develop it further according to the national situation. In this sense, the development and implementation phase will somewhat overlap.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	The SER clearly needs to be produced intentionally. It will require significant effort to compile, maintain and preserve.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	The records are tangible. The process leading up to the SER (identifying, discussing, selecting, interpreting, updating, etc.) can be seen as an intangible RK&M preservation element of the SER.				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission: **X**	Non-mediated transmission: **X**			
	It is anticipated that, particularly during repository operation, versions of the SER would be periodically renewed and that the SER would be actively maintained and preserved. If a final state is agreed upon, the SER may be transferred in both a mediated and non-mediated way.				

Mechanism	Set of essential records (SER)
Actors	The decision on SER implementation should be made by the regulator and/or the implementing agency. Rules for the selection, classification, maintenance, periodic review and short term preservation of the SER should be developed by the implementing agency in co-operation with regulators, archives and as many disciplines and stakeholders as relevant. The national archives shall be responsible for preserving the SER in the medium and long term. Other preservation institutes (e.g. local and international archives, servers of international co-operation bodies, education bodies) should be involved to create redundancy.
Main strengths/benefits	The SER provides detailed information on the repository system, selected specifically as to be an information, knowledge and decision-making resource for future society, particularly technicians, researchers and decision makers.
Specific issues/challenges	There is a need to develop a traceable and justifiable approach for the repository records classification and selection, taking into account regulations, archiving rules and stakeholder requirements. The durability and accessibility of the SER need to be maintained. Security issues may control some aspects of accessibility.
International dimension	The SER is intended mainly for local and national use. It is too detailed and specific to play a significant international role. Nevertheless, best practices can be shared and international bodies may also preserve national SERs in the longer term.
Connection to other approaches/ mechanisms	Dedicated record sets and summary files: KIF *(the KIF and SER should point to each other)* Memory institutions: archives Regulatory framework: National regulatory framework *(regulation will likely require the production and updating of a SER)* Oversight: *oversight related records (these (e.g. related to monitoring and land use) may be included in the SER)* Knowledge management Culture, education and art: Education, research and training
Information resources issued by the RK&M initiative	• NEA (forthcoming), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Compiling a Set of Records for a Radioactive Waste Repository*, OECD, Paris.
Other information resources	• IAEA (1999), *Maintenance of Records for Radioactive Waste Disposal*, IAEA-TECDOC-1097, IAEA, Vienna. • IAEA (2004), *Records for Radioactive Waste Management up to Repository Closure: Managing the Primary Level Information (PLI) Set*, IAEA-TECDOC-1398, IAEA, Vienna. • IAEA (2006), *Data Requirements and Maintenance of Records for Spent Fuel Management: A Review*, IAEA-TECDOC-1519, IAEA, Vienna. • IAEA (2007), *Long Term Preservation of Information for Decommissioning Projects*, Technical Report Series 467, IAEA, Vienna.
Examples	• The Detailed Memory File ("Dossier Détaillé de Mémoire") required in France (Decree 2007-1557 modified 28th June 2016) contains much of the information likely to be found in the SER. However, this is a single prepared document, rather than a compilation of existing records.

Memory institutions

Archives

Mechanism	Archives
Approach	Memory institutions
Definition/description	The term "archive" refers to both an accumulation of historical records and to the physical place where these records are located. It also denotes the institution or service in charge of the management and custody of these records. Archives generally consist of records (including both documents and objects), in analogue and/or digital format, that have been selected for permanent or long-term preservation, based on the grounds of their enduring administrative, informational, cultural, historical or legal value as evidence of the work of the creating organisation or programme. Archival records are mostly unpublished and almost always unique, unlike books or journals, for which many identical copies exist. Archives focus on collections rather than on individual records. Special care is taken to maintaining the context of each collection. The preservation of "original" material (i.e. in its original format, on the original medium) is particularly important. This means that archives, as institutions, are quite distinct from libraries with regard to their functions and organisation, although archival collections may sometimes be found within library buildings. National archives acquire, preserve and make available national records, in particular those created by national agencies. They usually establish policies and procedures for managing these records and assist national agencies in carrying out their records management responsibilities.

<table>
<tr><th>Mechanism</th><th>Archives</th></tr>
<tr><td>How does this mechanism contribute to RK&M preservation/ How can it be implemented?</td><td>Archives, as institutions, are responsible for selecting, acquiring, preserving and making available records in a coherent and contextually meaningful manner.
In the framework of a disposal project, the relevant records are usually firstly kept by the organisation(s) in charge of the project. This information repository is not strictly speaking an archive, but a management tool that is used to organise, preserve and access information during the entire duration of the project. Depending on national legislation and the administrative status of the organisation(s) in charge of disposal, the process of transferring records to one or more archives may be initiated at different points in time during the operational phase of the repository or after closure. At the latest, the process should take place when a transfer of responsibilities occurs (e.g. after repository closure).
Ultimately, the relevant records should be stored in one or more archives, preferably with a different geographic scope of influence to add to accessibility and redundancy. Given that repository records are of national relevance and importance, at least a subset of them is likely to be preserved by national archives. The possibility to establish an archive dedicated to repository records, with dedicated funding, at the national and/or international level, should also be taken into consideration.
Regarding the selection of repository records to be archived, see especially the “SER” mechanism.</td></tr>
<tr><td rowspan="8">Scope</td><td>Does the mechanism mainly preserve information, records, knowledge, memory or awareness?</td></tr>
<tr><td>Information: X | Records: X | Knowledge: | Memory: | Awareness:</td></tr>
<tr><td>Archives preserve records with information. By paying special attention to maintaining the context of and coherence among record collections, archives aim to support both users’ ability to understand, interpret and use the content of the records (knowledge) and a broader awareness of events, people, places and levels of knowledge in the past (memory). If a dedicated nuclear archive were to be established, its sheer existence would also support awareness.</td></tr>
<tr><td>What is the level of detail addressed/provided by the mechanism?</td></tr>
<tr><td>Low level of detail: | High level of detail: X</td></tr>
<tr><td>The “level of detail” is relative, but in the RK&M preservation context, the focus of (whole) archives is on knowledge supporting/enabling, detailed information, more than on awareness supporting/enabling, basic information.</td></tr>
<tr><td>What is the main geographical or administrative-political scope (development/implementation/ operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field “International dimension” further below.]</td></tr>
<tr><td>Local: X | Regional: X | National: X | International: | Virtual: X</td></tr>
<tr><td>Archives exist on different levels, notably the local, regional and national level. International archives are rare (see separate mechanism “International archiving activities”). Online archives with digital(ised) records also exist.</td></tr>
<tr><td rowspan="8">Timescales</td><td>Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term: X | Medium term: X | Short term: | Very short term:</td></tr>
<tr><td>While archives are always “used in the present”, their main aim is to preserve selected records for the longer timescales, rather than the very short and short term (although, as repository projects often extend over many decades, archived records may also be consulted prior to repository closure).</td></tr>
<tr><td>When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational: | Operational: | Pre-closure: X | Post-closure: X</td></tr>
<tr><td>For this mechanism, the implementation timescale refers to the transfer of records to archives. While the implementer will do some in-house “archiving”, this is not considered as transfer to an archive.
Depending on the national regulatory framework, the transfer of records directly related to the repository is likely to happen mostly in the pre- and post-closure phase.
Taking into account national archives that also establish policies and procedures for managing records, and assist national agencies in carrying out their records management responsibilities, the implementation timescale can be understood to also include the pre-operational and operational phase (as preparatory phases for the actual record transfer).</td></tr>
<tr><td>When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: X | Pre-operational: | Operational: X | Pre-closure: X | Post-closure:</td></tr>
<tr><td>Archives already exist. A dedicated archive may be developed during the operational and pre-closure timescales.</td></tr>
<tr><td rowspan="6">Characteristics</td><td>Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td>Intentional: X | Unintentional: | Cannot be controlled:</td></tr>
<tr><td>Archives are an intentional mechanism. This includes providing records to be archived.</td></tr>
<tr><td>Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td>Tangible: X | Intangible:</td></tr>
<tr><td>Archives and their content are tangible.</td></tr>
</table>

Mechanism	Archives
Characteristics	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission: **X**
	Archives use both mediated and non-mediated transmission. While the collection of records is continuously and actively maintained for preservation and accessibility purposes (mediated transmission), the content of the individual records is fixed and is transferred in a non-mediated way.
Actors	Archives can be developed and run by both government and private actors at all geographical levels. The establishment of a dedicated nuclear archive could be the shared responsibility of government, implementing and regulatory agencies. Archiving specialists should obviously be involved. Society at large should be made aware of the existence of the archive and the potential to make use of it.
Main strengths/benefits	The main mission of archives is the long-term preservation of collections of records in order to ensure access over an indefinite period of time. Access relates to both "form" (integrity of the information carrier) and "content" (understandability through providing coherence and context). As one or more public agencies are likely to be involved in radioactive waste management (e.g. the safety authority), their records are usually due to be delivered to the national archive. This ensures their preservation in the longer term – even when the legal framework of waste disposal does not include specific provisions related to repository records. The specific strengths of a dedicated national or international "nuclear archive", in comparison to a generic archive, need to be investigated. The existence of such an archive would make it easier to locate the relevant records.
Specific issues/challenges	If the waste disposal implementing agency is a private company, it may not be legally required to hand over its records to a public archive. This process would need to be defined and organised. For public archives, well-established standards for record collection and metadata already exist. These standards may not be entirely compatible with the specific needs related to geological repository records. From an archival point of view, e.g. records are considered "archival records" when they are no longer in use or when the corresponding process has been completed. The long timescales of the disposal process are a challenge in this respect. Therefore, requirements regarding the format and structure of records collections, as well as metadata and contextual information, media, language, retention periods, access and confidentiality must be developed in concert with the institutional stakeholders (in particular the regulator) for RK&M preservation. They also need to be compared to current archival policies and practices, as defined by international (e.g. ISO) and national standards. Outside legally defined usage, potential users must first recognise an information need in order to search and subsequently find the relevant information in archives. Other mechanisms should direct users to archives.
International dimension	Archives are usually part of a wider network. The management of archival collections (e.g. cataloguing) is governed by international standards. Specific benefits derived from international nuclear archives, as well as expected challenges, remain to be investigated.
Connection to other approaches/ mechanisms	International mechanisms: International archiving initiatives Dedicated record sets and summary files: SER; KIF Culture, education and art: Alternative reuse of the site and/or its infrastructure (*an archive could be established on-site)* Time capsules *(Mediated time capsules containing records can be seen as a particular sort of archive.)* Legal Framework: National legal framework; safeguards Oversight provisions *(Archives can serve oversight by preserving usable records. Oversight is also likely to produce records that will be archived.)*
Information resources issued by the RK&M initiative	• Ohnesorge, K.W., "Digital Preservation at the Swiss Federal Archives", in NEA (2011), *The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue*, Workshop proceedings. 11-13 October 2011 in Issy-les-Moulineaux, OECD, Paris. • NEA (2013), *The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding*, Proceedings of the second RK&M Workshop, 12-13 September 2012, Issy-les-Moulineaux, France, OECD, Paris. Items 31, 32 and 35 on archiving. • Tucker, S., "The Nuclear Decommissioning Authority (United Kingdom) Nuclear Archive: The importance of stakeholder engagement", in NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate*, 15-17 September 2014, Verdun, France, OECD, Paris.
Other information resources	• International Council on Archives, ICA (www.ica.org/en). • Council of Audiovisual Archives, CCAAA (www.ccaaa.org).
Examples	• National archives in each country. • Dedicated nuclear archive: Nucleus: The Nuclear and Caithness Archives, Wick, Scotland (www.highlifehighland.com/nucleus-nuclear-caithness-archives).

Libraries

Mechanism	Libraries				
Approach	Memory institutions				
Definition/description	A library refers to a place where collections of books, periodicals and other information materials like films, photographs and audio recordings or even archives, are kept. It may be a physical building or room and/or a virtual space. It provides physical or digital access to its collections. Library collections may be generic (such as in a national, a university or a municipal library) or highly specialised. National libraries may be responsible for collecting all books published in the country or relevant to the country.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Public libraries help structure and disseminate publicly available information. They hold materials of different genres, which helps to reach a broad audience. A dedicated section on "nuclear" or "radioactivity" or "radioactive waste management" can create awareness for the issue. The material in this section would be useful for keeping RK&M on particular disposal project and/or on the broader context of disposal projects, e.g. works on local history, on scientific background (e.g. radioactivity), etc. Libraries often also host reading groups, where the topic of waste disposal could be discussed based on materials in the library. In the short term, specialised libraries may contribute to the preservation of RK&M in the sense that they hold scientific information necessary to research, e.g. by the implementing agency, the regulator or R&D institutions. In the medium term, all relevant reports published by the implementer are likely to be kept at the national library, for example the KIF could be stored by public libraries at different locations, both in paper and in digital format.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records:	Knowledge: **X**	Memory: **X**	Awareness:
	Through their high accessibility, libraries promote the spread and preservation of information, knowledge, memory and/or awareness contained in the various materials in their collections. While specialised libraries may also preserve particular records, this is more the purpose of archives than of libraries in general.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**		High level of detail: **X**		
	Libraries contain material of a broad variety of detail and genres.				
	What is the main geographical or administrative-political scope (development/implementation/ operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional: **X**	National: **X**	International:	Virtual: **X**
	Libraries exist at various levels and often collaborate regionally, nationally and sometimes internationally. Virtual libraries are gaining in importance.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term: **X**	Very short term: **X**	
	Libraries preserve RK&M in the present and near future, but there are also quite a few libraries worldwide that are many centuries old.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational:	Pre-closure:	Post-closure:	
	Libraries already exist. One would try to make sure that national libraries and public libraries, especially those in the vicinity of disposal projects, contain a number of references on disposal projects from the pre-operational and operational phases onwards. Disposal projects could also include on-site or nearby library projects as a form of added value and dedicated RK&M preservation, which could be developed during all timescales.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational:	Operational:	Pre-closure:	Post-closure:
	Libraries already exist. The materials that could go into libraries are developed throughout all phases of the repository lifetime.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional: **X**	Cannot be controlled: **X**		
	Specialised libraries may be dedicated RK&M preservation mechanisms. The content of public libraries cannot be fully controlled. Neither can the existence and content of private or personal libraries.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	Libraries and their content are tangible.				

Mechanism	Libraries
Characteristics	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** / Non-mediated transmission:
	Libraries disappear when they are no longer actively maintained or funded. Libraries in general are primarily focused on making materials available for use, not so much on preserving original items (see Archives).
Actors	Libraries may be set up, managed and run, and used by a wide range of public and private actors at the local, regional, national or international level. Prior to the closure of the repository, the implementing and regulatory agencies and R&D institutions are likely to maintain specialised libraries to address their own information needs.
Main strengths/benefits	The strength of public libraries lies in their mission to make accessible a wide range of published materials to a broad audience. With the emergence of digital technologies, the potential to disseminate their contents have increased. Libraries usually give access to items that are not unique (there are copies in other places). As such, they ensure the preservation of multiple copies of relevant works, which enhances redundancy.
Specific issues/challenges	Unlike archives, whose mission is preservation, libraries are often user-driven. If there is no interest in waste repositories, libraries may not keep related items in their collections over time. If related items are there, users may unintentionally find radioactive waste disposal related information while visiting the library/browsing through the catalogue for other reasons. However, in general potential users must first recognise an information need in order to search and subsequently find the relevant information.
International dimension	National libraries are usually part of a wider, international network. The management of library collections (e.g. cataloguing) is governed by international standards.
Connection to other approaches/ mechanisms	Culture, education and art: Nuclear and related topics in (academic) education, research and training; Alternative reuse of the site and/or its infrastructure; Information dissemination activities Dedicated record sets and summary files: KIF International mechanisms: International inventories and catalogues
Information resources issued by the RK&M initiative	• J. Schröder and A. Sneyers, "INIS and its national implementation", in NEA (2013), *The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding*, Proceedings of the second RK&M Workshop, 12-13 September 2012 in Issy-les-Moulineaux, OECD, Paris.
Other information resources	—
Examples	• World Digital Library, a co-operative project of the Library of Congress, the United Nations Educational Scientific and Cultural Organization (UNESCO), and partner libraries, archives, and educational and cultural institutions from the United States and around the world www.wdl.org/en. • Europeana and the European Library https://pro.europeana.eu/project/europeana-libraries.

Museums

Mechanism	Museums
Approach	Memory institutions
Definition/description	Museums select and collect specific objects and artefacts and present them to the public, accompanied by contextual information. A wide range of museums exist, from large, generic institutions to small and highly specific collections, from focusing on works of the past to investigating the present and exploring the future.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Museums can contribute to RK&M preservation through preserving specific objects related to (the history of) disposal projects. Works of art commissioned or developed within a particular disposal project may also be acquired by a museum that will display them and take care of their preservation. Museums can also contribute more generally through exhibitions aimed at investigating current thinking and practices related to radioactive waste (short term) and through exhibitions aimed at recreating past radioactive waste management thinking and activities (medium term). The contextual information related to the objects will also be relevant, in itself and to enrich the RK&M preservation potential of the objects. Emerging virtual technologies offer potential that museums have begun to explore, aimed at complementing, enhancing, or augmenting the museum through personalisation, interactivity, user experience and richness of content. As part of their mission, museums organise exhibitions and conduct educational programmes aimed at reaching a wide audience. Such events and programmes facilitate learning in a less formal and often more sensory context than traditional education.

Mechanism	Museums
Scope	Does the mechanism mainly preserve information, records, knowledge, memory or awareness?
	Information: **X** | Records: | Knowledge: | Memory: **X** | Awareness: **X**
	Museums preserve items, usually unique and original, which in themselves and through the research and contextual information accompanying the objects and exhibitions, raise awareness and transfer information and memory. Specialised museums often also preserve knowledge, e.g. with items showing/explaining how things were done.
	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: **X** | High level of detail:
	The information accompanying museum objects and exhibitions for visitors often has a modest level of detail. However, the research done by museums (e.g. published as collection or exhibition catalogues) can offer particularly detailed and rich contextual information.
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: **X** | Regional: **X** | National: **X** | International: **X** | Virtual: **X**
	Museums can be found on various levels. Larger museums often collaborate internationally and draw international interest. Virtual museums and virtual museum content are gaining in importance.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: | Medium term: **X** | Short term: **X** | Very short term:
	Some museums are hundreds of years old. Museum objects may reach the long term.
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: | Operational: | Pre-closure: | Post-closure:
	Museums already exist. One would try to make sure that especially those in the vicinity of disposal projects and also national museums take up at least some items/exhibitions related to disposal projects from the pre-operational and operational phases onwards. Disposal projects could also include a dedicated, on-site or nearby nuclear (waste) museum project as a form of added value and dedicated RK&M preservation, which could be developed during all timescales.
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: **X** | Pre-operational: | Operational: | Pre-closure: | Post-closure:
	Museums already exist. The objects and exhibitions can be developed throughout all phases of the repository lifetime.
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: **X** | Cannot be controlled: **X**
	A dedicated radioactive waste disposal museum could be intentionally established. But for museums in general, it is the museum management and individual curators that are responsible for the selection of objects and exhibitions. Establishing collaborations with museums and funding of art can enhance the chances that museums dedicate attention to radioactive waste disposal projects and repositories.
	Is the mechanism mainly tangible or intangible?
	Tangible: **X** | Intangible:
	Although the artefacts are clearly tangible, the functions of education and enjoyment can be seen as more intangible components of RK&M preservation through museums. The same goes for storytelling by museum guides.
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission:
	Museums contribute to preserving historical objects. Museums and their items need to be continuously and actively maintained.
Actors	Museums may be set up and managed by a wide range of public or private actors at the local, regional and national level. Actors involved in the RK&M preservation function of museums include curators, conservators, artists, historians, guides and museum visitors.
Main strengths/benefits	Specialist industrial and technical museums are important means of protecting and interpreting industrial heritage. Compared with textual descriptions, artefacts (such as machinery or scientific equipment) may contribute to making processes more understandable. Museums and the storytelling performed in museums (e.g. in the framework of educational programmes or guided tours) contribute to passing on information in a way that is intended to be attractive to the general public. Even more than users of archives and libraries, museum visitors may learn about things of the past they were not aware of and not specifically looking for. With digital technologies, access to museums does not require physical presence, therefore making museum collections accessible to a large audience.

Mechanism	Museums
Specific issues/challenges	Depending on the context in which the museum was created and is being maintained, there may be little control over the contents that are displayed to the public. Museums can only exhibit a small percentage of their collections in their buildings. If interests shift, relevant artefacts may no longer be on show. Physical access to these items remains possible, but becomes more complicated.
International dimension	International standards are being developed for the management of museum objects and collections and international museum inventories exist. Larger museums often collaborate internationally and draw international interest. Exhibitions and objects can travel from one museum to another.
Connection to other approaches/ mechanisms	Culture, education and art: Alternative reuse of the site and / or its infrastructure; Information dissemination activities; Nuclear and related topics in art.
Information resources issued by the RK&M initiative	• H. Codée & E. Verhoef, "Using art, stories and cultural heritage to preserve knowledge and memory", in NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate*, 15-17 September 2014, Verdun, France, p. 55, OECD, Paris (explaining how, in the Netherlands, COVRA collaborates with regional museums by acting as a storage facility for collections that are not on display). • Ch. Jacobs, "Archival and museum curatorship challenges for RK&M preservation", in NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations. Proceedings of the International Conference and Debate*, 15-17 September 2014, Verdun, France, OECD, Paris.
Other information resources	International Council of Museums http://icom.museum
Examples	• National Museum of Nuclear Science & History (Albuquerque, New Mexico, US) www.nuclearmuseum.org • Perpetual Uncertainty. An exhibition of contemporary art in the nuclear Anthropocene exploring the complexity of knowledge and the deep time of radiation, that has been hosted by various museums (Bildmuseet Umeå, Z33 Hasselt, Malmö Konstmuseum) www.artscatalyst.org/perpetual-uncertainty-0 • The Belgium Museum for Radiology, in collaboration with similar museums in Remscheid-Lennep (Germany) and Palermo (Italy), located in the waiting room of a hospital in Brussels: www.radiology-museum.be and www.radiology-museum.be/index.php/en/virtual-museums/virtual-museum-brussels.

Markers

Surface markers

Mechanism	Surface markers				
Approach	Markers				
Definition/description	A surface marker is a long-lasting object that indicates an area of influence, power or danger. It is placed strategically at or near the site for immediate visual recognition. Surface markers are to be constructed with the most durable materials in order to support a lifetime that is as long as possible and to be designed to express messages that remain understandable for as long as possible. They can be inscribed with words, figures or pictograms.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	A surface marker can be an important mechanism for the preservation or regeneration of awareness about a repository, notably aimed at the medium and long term. A single marker or a system of markers can be installed at or near the site. Surface markers are conceived to be immobile (i.e. in permanent association with a site) and robust, in order to maximise survivability independent of human maintenance. They are meant to provide messages that are likely to be understandable across many generations. Depending on their material, structural design and intended time scope, the messages markers are intended to carry can range from "this is man-made" to more elaborate, technical information. In this sense, the idea is that even if other RK&M mechanisms are lost, markers could still preserve or regenerate awareness, notably with the aim of avoiding inadvertent intrusion into the disposal site and/or repository. Nevertheless, it is recommended to integrate surface markers into a systemic strategy, pointing to complementary RK&M preservation mechanisms if possible (e.g. in line with alternative reuse of the disposal site/infrastructure) and being pointed at by or being integrated with other mechanisms (e.g. land use controls, monitoring, intangible cultural heritage).				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records:	Knowledge:	Memory:	Awareness: **X**
	Surface markers would focus on preserving awareness. However, by reminding people of earlier events, surface markers at disposal sites can also support the preservation, and foster the regeneration, of memory. Their inscriptions are meant to convey information about the disposal site and the repository.				

Mechanism	Surface markers				
Scope	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**				High level of detail:
	Surface markers are mainly designed to preserve awareness and information with a low level of detail. Depending on the marking concept, memory panels or education rooms could be added to a marker (system) to provide more detailed information, but may not survive as long as the basic marker itself.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional:	National:	International:	Virtual:
	Markers work locally. Decisions related to the implementation of surface makers are likely to involve the national level. Marker designs can be discussed internationally.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term: **X**	Medium term: **X**	Short term:	Very short term:	
	Surface markers notably aim to preserve and regenerate awareness in the medium and long term.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational:	Pre-closure: **X**	Post-closure: **X**	
	For this mechanism, the implementation timescale refers to the positioning of the marker(s) on the site. Surface markers can be designed into the site during the operational phase, but will only be finalised once the facility is ready for closure or after closure. Surface markers may also be maintained in the post-closure phase.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure:
	Some surface markers already exist (hence "Done"). For this mechanism, the development timescale refers to both the underlying marking concept and the design of the marker. This can start as soon as a site is selected and a disposal concept decided upon (perhaps as part of the licence application) or throughout the operational phase (perhaps as part of the closure licence application).				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	Surface markers are an intentional mechanism.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	Surface markers can be integrated with intangible mechanisms such as commemorations, education, etc.				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission:	Non-mediated transmission: **X**			
	Surface markers are ultimately conceived as a form of non-mediated transmission. But they can also be subject to mediated transmission: maintenance schemes can be developed (e.g. linked to commemoration events) to check the effectiveness of their function, repair actions may take place after e.g. natural disasters or acts of vandalism, they can be taken up in cultural heritage schemes, etc. They can also evolve from mediated to non-mediated transmission over time.				
Actors	Surface markers have the potential to affect the alleged interests and/or feelings of many and have an actual direct connection with local communities. Therefore, it is recommended that actors other than the regulator and the implementing agency, e.g. local communities, semioticians, artists and architects, are involved. Marker prototypes can be developed and their effectiveness in communicating a message tested at visitor centres, e.g. by the general public or students.				
Main strengths/benefits	Surface markers historically are and continue to be a well-known mechanism to preserve awareness of areas of influence, power or danger. They are particularly aimed at material and epistemic durability and robustness, and thus designed to withstand societal and/or natural disruptions without reliance on mediated transmission. Apart from these benefits that are particularly valuable for the long term, for the medium term they also have the potential to be integrated into a mediated systemic strategy, in connection to multiple other mechanisms and with the involvement of multiple actors (e.g. complementary to land use controls, alternative reuse of the disposal site, intangible cultural heritage, education, art, local history, heritage inventories and catalogues, etc.).				

Mechanism	Surface markers
Specific issues/challenges	Overall, there are no straightforward, conclusive answers yet with regard to the objectives, messages and methods of marking. Surface markers can be vulnerable to theft and/or vandalism. Messages that are only intended to scare have proven ineffective in the past (e.g. the pyramids), but designing markers with more sophisticated, lasting messages is challenging. Their effectiveness depends on the shared symbolic universe of the producers and those addressed (think e.g. of Stonehenge), and, with regard to their aim of avoiding inadvertent human intrusion, men's curious or self-confident nature may supersede their messages. The RK&M project supports the idea that markers, if used, should be developed as part of a systemic RK&M strategy aimed at protecting and informing future generations.
International dimension	Surface markers do not add to RK&M preservation on an international level, but international collaboration and harmonisation of certain features (design, messages, pictograms, etc.) could aid RK&M preservation, today (through collaborative research) and in the future (presuming continued globalisation, shifts of borders, etc.).
Connection to other approaches/ mechanisms	Markers Memory institutions Culture, education and art Time capsules Regulatory framework Oversight provisions Dedicated record sets and summary files *(the mechanisms under these approaches can all refer/point to surface markers or include them in their workings)*
Information resources issued by the RK&M initiative	• NEA (2013), *A Literature Survey on Markers and Memory Preservation for Deep Geological Repositories,* Study prepared in the framework of the NEA Initiative on the Preservation of Records, Knowledge and Memory (RK&M) across Generations, OECD, Paris. • NEA (2014), "Markers – Reflections on Intergenerational Warnings in the Form of Japanese Tsunami Stones", NEA/RWM/R(2014)4, OECD, Paris. • Thomson and Craighead, "A temporary index", in NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate*, Constructing Memory (Construire la mémoire), An International Conference and Debate on the Preservation of Records, Knowledge and Memory of Radioactive Waste across Generations, 15-17 September 2014, Verdun, pp. 133-135, OECD, Paris. (The "Temporary Index" project is about creating a series of real-time numeric counters expressing radioactive decay. Each display will countdown in seconds, showing the time remaining before the given item of waste or a particular site is considered to be safe. As a first step, data projections have been displayed in art galleries. The next step will be to establish a network of these counters online, which can later be attached to places such as Google Earth. Ultimately, possibilities of building semi-permanent physical counters in the places referred to will be investigated, with a view to making them self (solar) powered. See www.thomson-craighead.net/temporary_index.html)
Other information resources	• Trauth, K.M., S.C. Hora and R.V. Guzowski (1993), *Expert Judgement on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant,* SAND92-1382 l UC–721, prepared *by* Sandia National Laboratories for the United States Department of Energy, Albuquerque, New Mexico and Livermore. • Wisbey, S. (2012). *Marking the Location of Radioactive Waste Disposals – A UK Perspective*, Waste Management Conference, Phoenix, Arizona, US. WM Symposia, US. • Pescatore, C. and J. Schröder (2014), *Markers and Deep Geological Repositories – Learning within the NEA Project on the Preservation of Records, Knowledge and Memory across Generations*, Waste Management Conference, Phoenix, Arizona, US. WM Symposia, US. • Graham, N. et al. (2018), "Nuclear, Landmarker for a Waste Isolation Site: International Architecture Competition", paper presented at Waste Management Conference, Phoenix, Arizona, US. WM Symposia, US. • Permanent Markers Implementation Plan for WIPP (2004), see Section 5.1 Large Surface Markers of : www.wipp.energy.gov/library/PermanentMarkersImplementationPlan.pdf.
Examples	• The stone marker at Argonne National Laboratory's Plot M radioactive waste burial site, in the Red Gate Woods area of the Cook County Forest Preserve District (where the word "no" was chiselled out in the sentence "The is no danger to visitors."), see www.flickr.com/photos/reznicek111/3022034303.

Monuments

Mechanism	Monuments
Approach	Markers
Definition/description	A visible and complex type of marker, i.e. a large building or an ensemble of structures. A monument may consist of several visible and less visible markers, e.g. to encircle an area.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	A monument is conceived to be immobile (i.e. in permanent association with a site) and robust, in order to maximise survivability independent of human maintenance. Due to its size, a monument can convey more information about a repository than a surface or sub-surface marker. It can be conceived to transfer this information in a non-mediated way. In this sense, a monument could be conceived as a "stand-alone" RK&M preservation mechanism, should other mechanisms become lost. Nevertheless, it is recommended to integrate monuments into a systemic strategy (e.g. hosting a time capsule, being in line with alternative reuse of the disposal site/infrastructure, referring to the KIF, being listed as cultural heritage).
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?
	Information: **X** | Records: | Knowledge: | Memory: **X** | Awareness: **X**
	Monuments would focus on preserving awareness. However, by reminding and informing people of earlier events, they can also foster the preservation of memory. They could also convey information about the more technical aspects of the disposal site and its content and may even include records.
	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: **X** | High level of detail:
	Monuments are notably designed to preserve awareness of the presence of a disposal site. The messages they are intended to carry can range from "this is man-made" to much more elaborate messages. Depending on the concept, information panels or education rooms could provide more detailed information, or a time capsule can be included. But the monument in itself will remain a mechanism with a rather low level of detail.
	What is the main geographical or administrative-political scope (development/implementation/ operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: **X** | Regional: | National: | International: | Virtual:
	Monuments work locally. Under certain conditions, e.g. with regard to their development and implementation, their scope can be said to extend indirectly to the regional and national level.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: **X** | Medium term: **X** | Short term: | Very short term:
	Monuments notably aim to preserve and regenerate awareness in the medium and long term.
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: | Operational: | Pre-closure: **X** | Post-closure: **X**
	Monumental markers can be designed into the site during the operational phase, but will only be finalised once the facility is ready for closure or after closure. They can be maintained in the post-closure phase.
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: | Pre-operational: **X** | Operational: **X** | Pre-closure: **X** | Post-closure:
	For this mechanism, the development timescale refers to both the underlying concept and the design of the monument. This can start as soon as a site is selected and a disposal concept decided upon (perhaps as part of the licence application) or throughout the operational phase (perhaps as part of the closure licence application).
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled:
	Monuments are an intentional mechanism.
	—
	Is the mechanism mainly tangible or intangible?
	Tangible: **X** | Intangible:
	Monuments can also be integrated with intangible mechanisms such as commemorations, education, tourism, etc.
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: | Non-mediated transmission: **X**
	Monumental markers can ultimately be conceived as a form of non-mediated transmission. But they can also be subject to mediated transmission: maintenance schemes can be developed (e.g. linked to commemoration events) to check the effectiveness of their function, repair actions may take place after e.g. natural disasters or acts of vandalism, they can be taken up in cultural heritage schemes, etc. They can also evolve from mediated to non-mediated transmission over time.

Mechanism	Monuments
Actors	The development and implementation of monumental markers would be a multidisciplinary and participatory endeavour, involving implementing agencies, local communities, architects, local/regional governments, engineers, etc.
Main strengths/benefits	Monumental structures are and continue to be a known mechanism to preserve awareness and regenerate memory of areas of influence, power or danger. They are particularly aimed at material and epistemic durability and robustness, and thus designed to withstand societal and/or natural disruptions without reliance on mediated transmission. Apart from these benefits that are particularly valuable for the long term, for the medium term they also have high potential to be integrated into a mediated systemic strategy, in connection to multiple other mechanisms and with the involvement of multiple actors (e.g. complementary to land use controls, alternative reuse of the disposal site, intangible cultural heritage, education and research, art, local history, heritage inventories and catalogues, etc.).
Specific issues/challenges	Building a robust monument able to withstand the effects of weather over centuries or even millennia entails significant costs, which, as compared to the potential and difficult to measure benefits it brings, may be considered as inappropriate by decision makers. Taking care of the monument over the first centuries in order to monitor its durability will also require funding, unless a completely passive evolution of the monument is taken into account from the time of design and construction. The effectiveness of monuments depends on the shared symbolic universe of the producers and the addressed – their initial intention may be lost over time.
International dimension	Monuments can attract international interest, e.g. in the context of tourism. They could also be listed in international inventories and catalogues.
Connection to other approaches/ mechanisms	Markers Memory institutions Culture, education and art Time capsules Regulatory framework Oversight provisions Dedicated record sets and summary files *(the mechanisms under these approaches can all refer/point to monuments or include them in their workings)*
Information resources issued by the RK&M initiative	—
Other information resources	Mainly archaeological sources. Not applied in the field of RWM yet.
Examples	• Egyptian Pyramids • Great Wall of China • Aztec temple sites • Osaka castle (hosts a time capsule)

Sub-surface markers

Mechanism	Sub-surface markers
Approach	Markers
Definition/description	Sub-surface markers are buried objects, placed directly between ground level and the disposal horizon, aimed at creating awareness of the presence of hazardous waste material at the site upon their discovery.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	The purpose of sub-surface markers is to deter inadvertent intrusions by ensuring that the presence and, to the degree possible, the nature of the repository is understood, or can be deduced in combination with other information sources. They can be inscribed with words, figures or pictograms to convey a particular message, and/or they may have man-made properties and/or properties that can be detected at a distance (e.g. strong magnetic fields). The number and distribution of the sub-surface markers can be designed to further contribute to understanding of their purpose after their discovery. A regular array, possibly in 3-D, would make it clear that the site had been host to significant human activity. Small markers (tokens) may be buried at various depths, in such a way that they will be progressively dispersed further in the landscape by erosion. Such markers may also be buried in the upper part of the access drifts and shafts, in order to further clarify that they are indicators of human activity and meant to indicate the presence of a hazardous waste repository. Well-designed sub-surface markers are meant to make a contribution to long-term RK&M preservation, because they would be located at the site and would exhibit maintenance-free longevity. They are notably meant to avoid inadvertent intrusion. Although the presence of sub-surface markers may lead to further site investigation, this will be undertaken in a context of awareness of previous human activity and remaining risks.

Mechanism	Sub-surface markers				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory or awareness?				
	Information:	Records:	Knowledge:	Memory:	Awareness: X
	Sub-surface markers are dedicated to raise awareness of the presence of a repository. Their inscriptions, their nature and their distribution could convey some basic information. Copies could also be preserved in archives, with accompanying contextual information, as a particular type of records.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**		High level of detail:		
	Sub-surface markers are meant to preserve awareness and information with a very low level of detail.				
	What is the main geographical or administrative-political scope (development/implementation/ operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional:	National:	International:	Virtual:
	Sub-surface markers work locally. Decisions related to their implementation are likely to involve the national stage. For the purpose of recognition, copies may also be distributed more widely, e.g. to schools, displayed in visitor centres, etc.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term: **X**	Medium term:	Short term:	Very short term:	
	Sub-surface markers are notably aimed at creating awareness in the long term. They may also play a role in oversight activities in the medium term.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational:	Pre-closure: **X**	Post-closure: **X**	
	Sub-surface makers can best be designed into the upper parts of the access ways (shafts and tunnels) of the repository and its surrounding environment during the pre-closure and early post-closure phase.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done:	Pre-operational:	Operational: **X**	Pre-closure: **X**	Post-closure:
	The concept and design of sub-surface markers can best be developed during the operational phase, but development is possible anytime once the site is known and the disposal concept decided upon.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	This mechanism is about intentionally placing sub-surface markers.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	Sub-surface markers are tangible.				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission:	Non-mediated transmission: **X**			
	Sub-surface markers are meant to reach future generations directly, without relying on the presence of intermediaries. But they might support mediated transmission, for example if a maintenance activity or even a ritual would be organised e.g. for re-burying markers exhumed by erosion. Copies could be preserved in archives as a particular type of records.				
Actors	The implementing agency should explicitly plan for the installation of sub-surface markers at the disposal site. The nature and design of any sub-surface marker should be widely discussed, with technical, administrative and multidisciplinary contributions (artists, semioticians, archaeologists, etc.) before making a decision.				
Main strengths/benefits	Sub-surface markers can have a very long lifetime. They are better protected from environmental factors, such as erosion by wind and rain, and from human threats, such as theft and vandalism, than those at the surface.				
Specific issues/challenges	Long-term erosion or major geomorphological changes could be disruptive to sub-surface markers. Slow degradation of the marker material may obscure or distort the message they carry. Amateur archaeologists, acting as "trophy hunters", may excavate the site for buried markers. The aim of the sub-surface markers may not be clear over time. Sub-surface markers should not interfere with the safety functions of isolation and containment nor change the conditions of the repository environment. Small sub-surface markers may be missed by a potential inadvertent intruder.				
International dimension	Some level of standardisation may be elaborated internationally for sub-surface markers. The inscriptions can be developed as to achieve transnational relevance.				

Mechanism	Sub-surface markers
Connection to other approaches/ mechanisms	Markers Regulatory framework Culture, education and art: Art; Intangible cultural heritage; Education and Information dissemination activities *(information about of the existence, look and meaning of sub-surface markers could be passed on via these mechanisms)* Oversight provisions: Monitoring *(the presence of sub-surface markers could be monitored)* Memory institutions: Archives *(a copy of a sub-surface marker can be archived)* Time capsules *(a copy of a sub-surface marker can be placed in a time capsule with accompanying information)*
Information resources issued by the RK&M initiative	NEA (2013), *A Literature Survey on Markers and Memory Preservation for Deep Geological Repositories*, study prepared in the framework of the NEA Initiative on the Preservation of Records, Knowledge and Memory (RK&M) across Generations, OECD, Paris.
Other information resources	Wisbey, S. and Hotzel, S. (2016). "Markers and Beyond: Categorizing Human Intrusion Situations to be Addressed in Sub-surface Marking Concepts", Waste Management Conference. Phoenix, Arizona, US. WM Symposia, US.
Examples	Buried objects are commonly used to deter excavation of gas pipes and electricity cables, although these are generally at shallow depth (up to a few metres).

Deep geological markers

Mechanism	Deep geological markers				
Approach	Markers				
Definition/description	Deep geological markers are buried objects, placed in the same or an adjacent geological horizon of a geological disposal facility, aimed at creating awareness of the presence of nearby hazardous waste material upon their discovery.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	The purpose of deep geological markers is that they would be intercepted prior to contact with the repository, aiming to further deter inadvertent and uninformed intrusions by ensuring that the presence, exact location and, to the degree possible, the nature of the repository is understood, or can be deduced in combination with other information sources. They can be inscribed with words, figures or pictograms to convey a particular message, and/or they may have physical properties that can be detected at a distance (e.g. strong magnetic fields) and/or understood as anthropogenic. The number and distribution of the deep geological markers can be designed to further contribute to understanding of their purpose after their discovery. For example, they may be used to delineate the extent of the disposal volume. The installation of deep geological markers can be undertaken as part of facility construction. Excavated access ways (shafts and tunnels) can host such markers, as can the environment surrounding the repository. Well-designed deep geological markers are meant to make a contribution to long-term RK&M preservation, because they are to be located very close to the repository and would exhibit excellent longevity. Deep geological markers are complementary to sub-surface markers.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information:	Records:	Knowledge:	Memory:	Awareness: **X**
	Deep geological markers are dedicated to raise awareness of the presence of a repository upon their discovery. Their inscriptions, their nature and their distribution may convey some basic information. Copies could also be preserved in archives, with accompanying contextual information, as a particular type of records.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail:	
	Deep geological markers are designed to provide limited information on the repository, but for a long period of time.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional:	National:	International:	Virtual:
	Deep geological markers work locally. Decisions related to their implementation are likely to involve the national stage. For the purpose of recognition, copies may also be distributed more widely, e.g. to schools, displayed in visitor centres, etc.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term: **X**	Medium term:	Short term:	Very short term:	
	Deep geological markers are notably aimed at the long term. They may also play a role in oversight activities in the medium term.				

<table>
<tr><th>Mechanism</th><th>Deep geological markers</th></tr>
<tr><td rowspan="6">Timescales</td><td>When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational: | Operational: X | Pre-closure: X | Post-closure:</td></tr>
<tr><td>Deep geological makers can be designed into the excavated access ways (shafts and tunnels) of the repository and its surrounding environment during the operational phase and at the early stage of closure activities.</td></tr>
<tr><td>When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: | Pre-operational: X | Operational: X | Pre-closure: | Post-closure:</td></tr>
<tr><td>The concept and design of deep geological markers can be developed once the site is known and the disposal concept decided upon. As part of facility construction, they should best be developed early in the operational phase.</td></tr>
<tr><td rowspan="8">Characteristics</td><td>Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td>Intentional: X | Unintentional: | Cannot be controlled:</td></tr>
<tr><td>While access galleries and shafts, once backfilled, will remain as deep geological traces that may be considered as unintentional markers, dedicated deep geological markers will have to be specially developed and implemented.</td></tr>
<tr><td>Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td>Tangible: X | Intangible:</td></tr>
<tr><td>Deep geological markers are tangible.</td></tr>
<tr><td>Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td>Mediated transmission: | Non-mediated transmission: X</td></tr>
<tr><td>Deep geological markers are meant to reach future generations directly, without relying on the presence of intermediaries. They may be accompanied by mediated transmission, e.g. with maintained sensors above ground pointing at them. They might also support mediated transmission when copies are used in e.g. education or preserved in archives as a particular type of records.</td></tr>
<tr><td>Actors</td><td>The implementing agency should explicitly plan for the installation of deep geological markers.
The nature and design of any deep geological marker should be widely discussed with technical, administrative and multidisciplinary contributions (artists, semioticians, archaeologists, material scientists, engineers, etc.) before making a decision.</td></tr>
<tr><td>Main strengths/benefits</td><td>Geological markers can have a very long lifetime. They are well protected from environmental factors, such as erosion by wind and rain, and from human threats, such as theft and vandalism. Their proximity to the repository can be seen as an advantage with regard to indicating its presence and creating awareness.</td></tr>
<tr><td>Specific issues/challenges</td><td>Slow degradation of the marker material may obscure or distort any message that they carry.
The aim of the deep geological markers may not be clear over time. And by raising curiosity once re-detected, deep geological markers might encourage excavation close to the waste.
Deep geological markers should not interfere with the safety functions of isolation and containment of the repository.</td></tr>
<tr><td>International dimension</td><td>Some level of standardisation may be elaborated internationally for deep geological markers. The inscriptions can be developed to achieve transnational relevance.</td></tr>
<tr><td>Connection to other approaches/ mechanisms</td><td>Markers
Regulatory framework
Culture, education and art: art; intangible cultural heritage; education and Information dissemination activities (information about of the existence, look and meaning of sub-surface markers could be passed on via these mechanisms)
Oversight provisions: monitoring (in case the presence of deep geological markers could be monitored)
Dedicated record sets and summary files (unlike other RK&M preservation mechanisms, deep geological markers cannot be looked at to get confirmation of their existence; therefore it is crucial that information about them is available in the SER and KIF)
Memory institutions: Archives (a copy of deep geological marker may be archived)</td></tr>
<tr><td>Information resources issued by the RK&M initiative</td><td>NEA (2013), A Literature Survey on Markers and Memory Preservation for Deep Geological Repositories, study prepared in the framework of the NEA Initiative on the Preservation of Records, Knowledge and Memory (RK&M) across Generations, OECD, Paris.</td></tr>
<tr><td>Other information resources</td><td>—</td></tr>
<tr><td>Examples</td><td>• Deep geological markers may be installed in spent oil and gas wells, as they are being isolated and remediated. They may also be used in mine tunnels and vaults.
• Some inspiration may also be drawn from “deep marine markers”, designed to identify and protect sub-sea cables. However, these are not isolated and protected by cover rocks.</td></tr>
</table>

Surface traces

Mechanism	Surface traces				
Approach	Markers				
Definition/description	Surface traces are any long-lasting feature(s), visible at the ground surface without excavation, which can be identified as originating from the use of a site for a large-scale, industrial activity. The traces must be anthropogenic, they may consist of residual elements of site structures (mounds, walls, foundations, etc.) but also of human-induced changes to the natural environment (altered water courses, excavations, etc.). Depending on the nature and the scale of the features and the degree to which they blend with the local environment as they age, they may be more visible from above (e.g. by flying over the site, google earth, etc.).				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	If a site is closed and abandoned without full restoration, adventitious surface traces will be inevitable. Surface traces may also be deliberately left in situ, or even created by design. Surface traces are notably conceived as supporting RK&M preservation in the long term, when oversight has lapsed. The idea is that they will preserve or recreate awareness, by alerting the observer to previous activity at the site. In themselves, they are unlikely to provide a straightforward message about the facility, but they can stimulate interest in previous activities at the site, and may thus contribute to the restoration of information, memory and/or knowledge relating to the operations conducted there. In order to fulfil this function they will need to be recognised and linked to other information sources, on-site (e.g. sub-surface markers) or off-site (e.g. archives).				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information:	Records:	Knowledge:	Memory:	Awareness: **X**
	Surface traces can only act to provide awareness.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**		High level of detail:		
	Surface traces can only act to provide awareness, for example that the site had previously been used for significant human industrial activity, which is a message with a low level of detail.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional: **X**	National:	International:	Virtual:
	Over time, surface traces are likely only to provide their input at a local or regional scale. Their deliberate development can be addressed nationally or even internationally.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term: **X**	Medium term:	Short term:	Very short term:	
	Surface traces may aid RK&M preservation in the medium term (e.g. pointing out the dimension of the repository, complementing alternative reuse of the site, being part of monitoring schemes), but are mainly aimed at the long term.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational:	Pre-closure: **X**	Post-closure: **X**	
	If no deliberate action is undertaken to remove them, surface traces will appear throughout the operational, pre- and post-closure phase. The deliberate implementation of surface traces would notably take place during the pre-closure and/or post-closure phase.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done:	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure:
	The concept and design of deliberate surface traces can be developed once the site is known and the disposal concept decided upon, possibly in connection with the development of markers or monuments.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional: **X**	Cannot be controlled: **X**		
	Intentionally implemented surface traces may have higher chances to persist and maintain awareness, but unintentional traces are likely to be left after closure of the repository unless serious efforts are made to remove them. In this sense, some degree of residual surface traces is likely to be uncontrollable.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	This mechanism refers to tangible traces on the surface of the disposal site.				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission:		Non-mediated transmission: **X**		

Mechanism	Surface traces
Characteristics	Surface traces can be part of mediated transmission mechanisms (e.g. alternative reuse of the disposal site, intangible cultural heritage, education and research) and may be deliberately maintained over time, but are notably conceived as a mechanism that does not rely on intermediary generations to maintain/incite awareness.
Actors	As a deliberate RK&M preservation mechanism, it is recommended that a variety of actors and disciplines are consulted about the concept and design of surface traces. This should extend beyond the implementing agency and regulator, e.g. geologists, ecologists, historians, archaeologists, local communities, and make connections with other on-site RK&M preservation mechanisms (e.g. markers, alternative reuse of the disposal site/infrastructure).
Main strengths/benefits	Whether intentional or unintentional, surface traces are likely to remain visible at a disposal site for a very long time. Their implementation may be achieved at a reasonably low cost, or even at no additional cost when evolving naturally from the disposal project (e.g. altered waterways, excavations).
Specific issues/challenges	It may be impossible to restore the surface environment to a purely "natural" state. In other words, this mechanism is hard to avoid and thus best taken into account and addressed explicitly. For instance, surface traces at a site for which other RK&M preservation mechanisms have been lost may lead to sub-surface investigations or excavations (industrial archaeology). In themselves, surface traces are unlikely to provide a straightforward message about the disposal site. Complementary mechanisms thus need to be provided (e.g. sub-surface markers, references to the meaning of the surface traces in other mechanisms such as the SER and the KIF).
International dimension	The interest in industrial landscapes is growing internationally. The concept and design of surface traces and their evolution over time may be discussed and followed up internationally.
Connection to other approaches/ mechanisms	Markers *(should aid surface traces in fulfilling their function of avoiding inadvertent intrusion)* Dedicated repository records: SER; KIF *(can explain the meaning of surface traces)* Culture, education and art: Alternative reuse of the site and/or its infrastructure; industrial heritage; local history societies; education, research and training *(can aid the preservation of awareness and meaning of the surface traces)* Oversight provisions: Land use control.
Information resources issued by the RK&M initiative	• A. Storm, "Heritage messages of a post-nuclear nature", in NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate*, 15-17 September 2014, Verdun, France, p. 71-73, OECD, Paris. • NEA (2013), *A Literature Survey on Markers and Memory Preservation for Deep Geological Repositories*, study prepared in the framework of the NEA Initiative on the Preservation of Records, Knowledge and Memory (RK&M) across Generations, OECD, Paris.
Other information resources	• Wisbey, S. (2012). "Marking the Location of Radioactive Waste Disposals – a UK Perspective", Waste Management Conference, Phoenix, Arizona, US. WM Symposia, US. • Storm, A. (2014), *Post Industrial Landscape Scars*, Palgrave Macmillan, US.
Examples	• Neolithic hill forts • Mediaeval strip farming • Open cast mines and quarries

Time capsules

Large visible time capsules

Mechanism	Large, visible time capsules
Approach	Time capsules
Definition/description	Large, visible time capsules are purpose-built, sealed enclosures of a considerable size, kept visibly above ground on the disposal site or elsewhere. They contain a cache of information items (which can include documents as well as relatively small objects), dedicated to the repository or including references to the repository among information about other topics. The large, visible type of time capsules are mainly designed to be opened at pre-defined time(s) in the future.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Large visible time capsules can contain a large variety of information items, which should be chosen and combined to be as self-explanatory as possible. The capsules can be designed for opening at an indefinite time (non-mediated transmission), or, in the case of some specific large, visible time capsules, notably for opening and re-sealing at specific times (mediated transmission). In the latter case, they may be designed, potentially with duplicate capsules, to be opened, checked/curated, and re-closed. The opening times can be inscribed on the outer surface of the capsule or an outer enclosure. The openings of large, visible time capsules are often overseen by a group of people and connected to commemorations or rituals, which creates an additional, intangible form of RK&M preservation, complementary to the content of the time capsule. When placed at the disposal site, they may also serve in first instance as a type of marker.

Mechanism	Large, visible time capsules
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?
	Information: **X** | Records: **X** | Knowledge: | Memory: | Awareness: **X**
	Time capsules have the potential to preserve records (e.g. a hard copy of the KIF, a digital copy of the SER). Additionally, when opened they may contribute to the regeneration of knowledge (when e.g. interpretable RWM or radiation protection guidelines or perhaps a measuring device with a manual are discovered upon their opening) and memory (by means of carrying contextual information, pictures, newspaper articles, small objects, etc). When placed at the disposal site, large visible time capsules are well suited to preserve awareness (even without being opened) and, when inscribed, some limited information.
	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: | High level of detail: **X**
	Depending on their content, large time capsules can preserve information with a high level of detail.
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: **X** | Regional: **X** | National: **X** | International: | Virtual:
	The awareness preservation function of on-site, large and visible time capsules functions locally. But the opening of a large, visible time capsule, especially when organised as a commemoration or ritual, would be a noteworthy event, to be communicated on a national or even an international scale. Virtual coverage of the content and the opening of the time capsule could also be possible.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: **X** | Medium term: **X** | Short term: | Very short term:
	Time capsules are typically designed for a minimum of 100 years, some have planned lifetimes for over 6000 years. Depending on their opening strategy, they can target the medium term as well as the long term (in which case they may aid to install a renewed period of oversight).
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: | Operational: | Pre-closure: **X** | Post-closure: **X**
	The implementation of this mechanism refers to the closure of the filled time capsule and its definitive emplacement. In order for them to include as much information as possible about the disposal project, this would happen in the pre- or post-closure phase.
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: **X** | Pre-operational: | Operational: **X** | Pre-closure: **X** | Post-closure:
	Some time capsules already exist (hence: done), but these are not related to disposal projects. Repository related information may also be added to existing, mediated time capsules if such adding of information fits their strategy. The development of new time capsules dedicated to or including repository information would best be developed during the operational phase, to be ready for installation upon repository closure.
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled:
	Time capsules are a clear example of intentional implementation.
	Is the mechanism mainly tangible or intangible?
	Tangible: **X** | Intangible:
	Large time capsules and their content are tangible. Strategies around their opening are intangible.
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: | Non-mediated transmission: **X**
	Time capsules can function and notably be seen as a non-mediated RK&M transmission mechanism. Nevertheless, visible time capsules can be developed to deploy a mediated transmission mode (including maintenance, openings, content checks/updates and re-sealing), too. Then, they combine both mediated and non-mediated transmission modes.
Actors	Time capsules can involve a very large array of actors (families, corporations, societies, etc.). Large, visible time capsules dedicated to waste disposal related RK&M preservation could be the responsibility of the implementing agency, working alongside the host community and local authorities, and involving multiple disciplines (communication specialists, material scientists, artists, etc.) and organisations (e.g. local history societies) for their development and implementation. National and international agencies may be involved e.g. for registering their existence.

Mechanism	Large, visible time capsules
Main strengths/benefits	Large time capsules can be designed to be visible, robust, immobile and long-lasting. Some time capsules have planned lifetimes of over 6 000 years. They are thus fit for non-mediated transmission aimed at the long term. The time capsule concept is well developed and "ready-to-go". The opening of the (control) capsule at regular intervals provides the basis for a recurring ritual, as well as the opportunity to apply the most recent preservation techniques for improving the longevity of its content and potentially arresting or reversing degradation. Overall, time capsules have the potential to be well-integrated with other mechanisms within a systemic approach (see also below), but they can ultimately also preserve an independent RK&M function should other mechanisms have failed.
Specific issues/challenges	Large, visible time capsules may be expensive to develop and install, and may quite quickly be viewed as anachronistic. Quality control related to their content over time cannot be assured. The relevance and interpretability of their content cannot be guaranteed over time, especially in the case of non-mediated transmission. They are also vulnerable to naturally and human-induced degradation (severe weather conditions, vandalism).
International dimension	There is general interest in time capsules across the international community (and a number of informal associations, such as the International Time Capsule Society). Large time capsule projects are discussed and registered internationally.
Connection to other approaches/ mechanisms	Markers: Surface markers; Monuments *(time capsules can be seen as a particular type of marker themselves and they can also work together with other markers, e.g. being part of a monument)* Memory Institutions: Archives *(a maintained time capsule containing records can be seen as a sort of archive or a complement to traditional archives)* International Mechanisms *(international time capsule societies and registers exist)* Dedicated Repository Records: SER; KIF *(can be included in a large time capsule)* Culture, Education and Art: Local history societies *(can be involved with the content of time capsules)*; Intangible cultural heritage *(openings can be part of commemorations or rituals)* Oversight *(maintained time capsules can form part of oversight activities and oversight information can be included in their content)*
Information resources issued by the RK&M initiative	• Pescatore, C. and Van Luik, A. (2016). Millennial Time Capsules as a Promising Means for Preserving Records for Future Generations. Waste Management Conference. Phoenix, Arizona, USA. WM Symposia, USA
Other information resources	• Jarvis, W. E. (2003). Time Capsules: a cultural history. McFarland & Co., Inc. Jefferson, North Carolina.
Examples	• The International Time Capsule Society (ITCS) in Atlanta USA provides a registry of time capsules around the world, making sure that they are properly recorded. They provide a free online registration form for anyone wishing to register a time capsule. The ITCS has a registry with about 1400 groups and it estimates there are 14 000 to 15 000 in existence. https://crypt.oglethorpe.edu/international-time-capsule-society/ • The Osaka Castle time capsule is a "dual-time" time capsule: two identical time capsules were buried in 1970, with the control version designed to be recovered in the year 2000, and every 100 years thereafter. See http://panasonic.net/history/timecapsule/ • The Crypt of Civilization Time Capsule at Oglethorpe University, sealed on May 28, 1940 and not to be opened until May 28, 8113. See http://crypt.oglethorpe.edu/

Large invisible time capsules

Mechanism	Large, invisible time capsules
Approach	Time capsules
Definition/description	Large, invisible time capsules are purpose-built, sealed enclosures of a considerable size, buried at or near the disposal site or elsewhere. They contain a cache of information items (which can include documents as well as small objects), dedicated to the repository or including references to the repository among information about other topics. They can be designed to be opened at pre-defined time(s) in the future or upon accidental discovery.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Large invisible time capsules can contain a large variety of information items, which should be chosen and combined to be as self-explanatory as possible. The capsules can be designed for opening at an indefinite time (non-mediated transmission), or for opening and re-sealing at specific times (mediated transmission). In the latter case, they may be designed, potentially with duplicate capsules, to be opened, checked/curated, and re-closed. The opening time(s) can be inscribed on the outer surface of the capsule, an outer enclosure or an accompanying surface marker. The openings of large, buried time capsules are often overseen by a group of people and connected to commemorations or rituals, which creates an additional, intangible form of RK&M preservation, next to the content of the time capsule. When placed at the disposal site, they may also serve in first instance as a type of sub-surface marker to create awareness.

Mechanism	Large, invisible time capsules				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records: **X**	Knowledge:	Memory:	Awareness:
	Time capsules have the potential to preserve records (e.g. a hard copy of the KIF, a digital copy of the SER). Additionally, when opened they may contribute to the regeneration of knowledge (when e.g. interpretable RWM or radiation protection guidelines or perhaps a measuring device with a manual are discovered upon their opening) and memory (by means of carrying contextual information, pictures, newspaper articles, small objects, etc). When placed below surface at the disposal site, they may also serve, in first instance, as a sub-surface marker to create awareness and, when inscribed, some limited information upon their discovery.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail:			High level of detail: **X**	
	Depending on their content, large time capsules can preserve information with a high level of detail.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional: **X**	National: **X**	International:	Virtual:
	The awareness raising function of on-site, large and invisible time capsules functions locally. But their opening, especially when organised as a commemoration or ritual, could be appreciated as a noteworthy event, to be communicated on a national or even an international scale. Virtual coverage of the content and the opening of the time capsule could also be possible.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term: **X**	Medium term: **X**	Short term:	Very short term:	
	Time capsules are typically designed for a minimum of 100 years, some have planned lifetimes of over 6000 years. Depending on their opening strategy, they can target the medium term as well as the long term (in which case they may contribute to initiating a renewed period of oversight).				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational:	Pre-closure: **X**	Post-closure: **X**	
	The implementation of this mechanism refers to the closure of the filled time capsule and its definitive emplacement underground. In order for them to include as much information as possible about the disposal project, this would happen in the pre- or post-closure phase.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational:	Operational: **X**	Pre-closure: **X**	Post-closure:
	Some sub-surface time capsules already exist (hence: done), but these are not related to disposal projects. Repository related information may also be added to existing, mediated time capsules if such adding of information fits their strategy. The development of new time capsules dedicated to or including repository information would best be developed during the operational phase, to be ready for installation upon repository closure.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	Time capsules are a clear example of intentional implementation.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	Large time capsules and their content are tangible. Strategies around their opening are intangible.				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission:	Non-mediated transmission: **X**			
	Time capsules can function and notably be seen as a non-mediated RK&M transmission mechanism. Nevertheless, large time capsules can be developed to deploy a mediated transmission mode (including retrieval, maintenance, openings, content checks/updates and re-sealing), too. Then, they combine both mediated and non-mediated transmission modes.				
Actors	Time capsules can involve a very large array of actors (families, corporations, societies, etc.). Large, invisible time capsules dedicated to waste disposal related RK&M preservation could be the responsibility of the implementing agency, working alongside the host community and local authorities, and involving multiple disciplines (communication specialists, material scientists, etc.) and organisations (e.g. local history societies) for their development and implementation. National and international agencies may be involved e.g. for registering their existence.				

Mechanism	Large, invisible time capsules
Main strengths/benefits	Large, invisible time capsules can be designed to be robust, immobile and long-lasting. They are better protected from environmental factors, such as erosion by wind and rain, and from human threats, such as theft and vandalism, than those at the surface. Some time capsules have planned lifetimes of more than 6000 years. They are thus fit for non-mediated transmission aimed at the long term. The time capsule concept is well developed and "ready-to-go". The opening of the (control) capsule at regular intervals provides the basis for a recurring ritual, as well as the opportunity to apply the most recent preservation techniques for improving the longevity of its content and potentially arresting or reversing degradation. Overall, time capsules have to potential to be well-integrated to other mechanisms within a systemic approach (see also below), but they can ultimately also preserve an RK&M function should other mechanisms have failed.
Specific issues/challenges	Large, invisible time capsules may be expensive to develop and install, and may quite quickly be seen as anachronistic. Quality control related to their content over time cannot be assured. The relevance and interpretability of their content cannot be guaranteed over time, especially in the case of non-mediated transmission. The existence of invisible time capsules may be forgotten over time and they may be missed by potential inadvertent intruders.
International dimension	There is general interest in time capsules across the international community (and a number of informal associations, such as the International Time Capsule Society). Large time capsule projects are discussed and registered internationally.
Connection to other approaches/ mechanisms	Markers: Sub-surface markers; Monuments *(time capsules can be seen as a particular type of sub-marker themselves and they can also work together with other markers, e.g. when surface markers or monuments point to them)* Memory Institutions: Archives *(a maintained time capsule containing records can be seen as a sort of archive or a complement to traditional archives)* International Mechanisms *(international time capsule societies and registers exist)* Dedicated Repository Records: SER; KIF *(can be included in a time capsule)* Culture, Education and Art: Local history societies *(can be involved with the content of time capsules)*; Intangible cultural heritage *(openings can be part of commemorations or rituals)* Oversight *(maintained time capsules can form part of oversight activities and oversight information can be included in their content)*
Information resources issued by the RK&M initiative	• Pescatore, C. and Van Luik, A. (2016), Millennial Time Capsules as a Promising Means for Preserving Records for Future Generations. Waste Management Conference, Phoenix, Arizona, USA. WM Symposia, USA
Other information resources	• Jarvis, W. E. (2003). Time Capsules: a cultural history. McFarland & Co., Inc. Jefferson, North Carolina. • The International Time Capsule Society (ITCS), see https://crypt.oglethorpe.edu/international-time-capsule-society.
Examples	The Westinghouse Time Capsules, created for the 1939 and 1964 World's Fairs respectively. Both are buried 50 feet below Flushing Meadows–Corona Park in New York. They are to be opened in the year 6939, five thousand years after the first capsule was sealed. See https://archive.org/details/storyofwestingho00pendrich

Small time capsules

Mechanism	Small time capsules				
Approach	Time capsules				
Definition/description	This mechanism refers to small, purpose-built, sealed enclosures containing a cache of information items (which can include short documents as well as small objects). They would be buried between the ground level and the disposal horizon and/or in the outer parts of the repository, or they can be integrated into e.g. a monument or surface marker.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Small time capsules at the disposal site would aim to create awareness of the repository upon their discovery and to transfer the information they preserve upon their opening. They would probably be placed underground, in the disposal facility openings and access ways, at depths ranging from the disposal horizon to the top of the defined "barrier strata" that make up the host geology. They would work in a similar manner to small sub-surface and small deep geological markers, with the difference that their content would preserve more information than the inscriptions, design and distribution of sub-surface markers can preserve. They would notably be designed to be opened upon their discovery, rather than to be opened at regular intervals as part of a commemoration or ritual.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records: **X**	Knowledge:	Memory:	Awareness:

Mechanism	Small time capsules
Scope	Small time capsules have the potential to preserve relatively short records (e.g. the KIF). Additionally, when opened they may contribute to the regeneration of some knowledge (when e.g. short interpretable RWM or radiation protection guidelines or perhaps a small measurement device with a short manual are discovered upon their opening) and memory (by means of carrying contextual information, a picture, a drawing, a newspaper article, small objects, etc). When placed below surface at the disposal site, they may also serve in first instance as a small sub-surface marker to create awareness.
	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: | High level of detail: **X**
	Due to their size, the level of detail provided by small time capsules cannot be very detailed, but, due to the fact that they contain a cache of information, still relatively detailed compared to e.g. sub-surface markers.
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: **X** | Regional: | National: | International: | Virtual:
	Small time capsules function on a local scale (i.e. upon discovery). If their discovery and opening would be appreciated as a noteworthy event, their RK&M preservation scope may broaden to the national level. For the purpose of recognition, copies may also be distributed more widely, e.g. to schools, displayed in visitor centres. They may also have the potential to be elaborated virtually.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: **X** | Medium term: **X** | Short term: | Very short term:
	Time capsules are typically designed for a minimum of 100 years, and some have planned lifetimes of more than 6 000 years. They can work as a mechanism for the long term, when oversight would have been lost, and/or they can support oversight activities during the medium term.
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: | Operational: **X** | Pre-closure: **X** | Post-closure: **X**
	Small time capsules can be designed into the excavated access ways (shafts and tunnels) of the repository and its surrounding environment during the operational phase and at the early stage of closure activities. They can also be installed below surface in the early post-closure phase.
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: | Pre-operational: **X** | Operational: **X** | Pre-closure: **X** | Post-closure:
	Small, invisible time capsules already exist, but they have not yet been applied within the context of disposal projects. Time capsules would need to be developed during the planning and operations of a repository, before its closure.
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled:
	Time capsules are a clear example of intentional implementation.
	Is the mechanism mainly tangible or intangible?
	Tangible: **X** | Intangible:
	Small time capsules and their content are tangible.
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: | Non-mediated transmission: **X**
	Small time capsules would normally function as a non-mediated transmission mechanism aimed to reach future generations directly, without relying on the presence of intermediaries.
Actors	The implementing agency could explicitly plan for the installation of small time capsules at the disposal site, working alongside the host community and local authorities, and involving multiple disciplines (historians, material scientists, etc.).
Main strengths/ benefits	Small time capsules can be designed to be robust and long-lasting. Being buried they are well protected from environmental factors, such as erosion by wind and rain, and from human threats, such as theft and vandalism. Their proximity to the repository can be seen as an advantage with regard to indicating and informing about its presence and nature.
Specific issues/ challenges	Long-term erosion or major geomorphological changes could be disruptive to small time capsules. Slow degradation of the time capsule content may obscure or distort the information it carries. Amateur archaeologists, acting as "trophy hunters", may excavate the site for small buried time capsules. They should not interfere with the safety functions of isolation and containment nor change the conditions of the repository environment. Small time capsules may be missed by a potential inadvertent intruder.

Mechanism	Small time capsules
International dimension	Some level of standardisation may be elaborated internationally for small time capsules dedicated to repositories. Their design and content could be discussed internationally so as to achieve transnational recognition and relevance.
Connection to other approaches/ mechanisms	Time capsules *(small time capsules could be conceived as comprised versions of large ones)* Markers *(small time capsules can be seen as a particular type of deep geological or sub-surface marker themselves and they can also work together with other markers, e.g. when surface markers or monuments point to them)* Dedicated Repository Records: KIF *(can be included in a small time capsule)* Culture, Education and Art: Local history societies *(can be involved with the content of time capsules)* Oversight *(small time capsules can form part of oversight activities such as monitoring)*
Information resources issued by the RK&M initiative	• Pescatore, C. and Van Luik, A. (2016). Millennial Time Capsules as a Promising Means for Preserving Records for Future Generations. Waste Management Conference. Phoenix, Arizona, USA. WM Symposia, USA
Other information resources	—
Examples	• NASA placed a kind of small time capsule aboard Voyager 1 and 2, intended to communicate a story of our world to extraterrestrials. The Voyager message is carried by a phonograph record, a 12-inch gold-plated copper disk containing sounds and images selected to portray the diversity of life and culture on Earth. • Small time capsules are used in informal settings, e.g. in family ceremonies, and there is a market for small time capsule containers e.g. in stainless steel.

Culture, education and art

Industrial heritage

Mechanism	Industrial heritage				
Approach	Culture, Education and Art				
Definition/description	At the end of the operational phase, the disposal site – in particular the surface facilities – may be considered as industrial heritage, i.e. evidence of activities that had and continue to have historical, cultural and industrial relevance and consequences. Preserved industrial sites are considered an important means of protecting and interpreting industrial heritage.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	If the remaining accessible surface facilities associated with the disposal site are considered industrial heritage and maintained as such, they can act as a marker of the repository. As such they would maintain awareness and memory of the repository and could also foster the preservation and interpretation of any records or artefacts left on-site. Preservation measures may be applied for emblematic buildings and infrastructure (which could include former inbuilt technologies, machineries or equipment) used during repository operation. The site may also be registered in industrial heritage inventories and included in heritage (scientific, educational, historic) tourism schemes.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information:	Records:	Knowledge:	Memory: **X**	Awareness: **X**
	This mechanism will notably preserve awareness and memory, with a level of information depending on the industrial heritage preservation scheme. Surface infrastructures may also contain specific records and knowledge (reconstruction) tools, depending on what is being preserved.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail:	
	Depending on the content of the surface infrastructure and the additional information provided in the framework of industrial heritage, more detailed information and knowledge may also be preserved.				
	What is the main geographical or administrative-political scope (development / implementation / operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional: **X**	National:	International:	Virtual:
	Industrial heritage draws attention on a regional and local level. International heritage bodies could become involved, which may give rise to some international awareness and potentially link the site to other similar sites across the world. If industrial heritage is registered (online), its scope can broaden to include the national, international and virtual level.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term:	Very short term:	
	This mechanism targets the post-operational repository phase, while oversight is operating.				

Mechanism	Industrial heritage				
Timescales	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational:	Pre-closure: **X**	Post-closure: **X**	
	Promoting surface facilities to become industrial heritage could start in the late operational phase. Presuming that the status of (some) facilities will only become clear after the operational phase, the element is likely to be fully implemented throughout the pre-closure and early post-closure phase.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational:	Operational:	Pre-closure: **X**	Post-closure: **X**
	The concept of maintaining previous industrial facilities as industrial heritage for the purpose of maintaining memory of past activities is readily developed and has been applied before. Presuming that the status of (some) facilities will only become clear after the operational phase, the element is likely to be explicitly developed mainly throughout the pre-closure and early post-closure phase.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled: **X**		
	See Specific issues/challenges below.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	Although explicitly tangible, industrial heritage, in common with most tangible elements in the field of culture, education and art, will likely also have an intangible aspect (e.g. storytelling, possibly maintenance).				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission: **X**	Non-mediated transmission: **X**			
	Surface facilities may just be left to decay and also preserve awareness and some memory for a certain time as such, but in this case they would not be classified as "industrial heritage". Therefore, in industrial heritage, a mediated transmission mode component is involved.				
Actors	Society at large defines what should be regarded as cultural heritage. Formal registration of sites and architecture in cultural heritage inventories, however, is usually the responsibility of local/regional, national or international heritage organisations. Steps may be taken before site closure to propose including the facility in such an inventory. The implementing agency may be asked to prepare the conversion of former facilities into cultural heritage buildings. Depending on the regulation about the surveillance phase, the responsibility for maintenance of such cultural heritage may be transferred sooner or later to cultural heritage organisations. Local communities can be involved in the planning and functioning of the industrial heritage site.				
Main strengths/ benefits	The close geographic connection to the repository can be considered an advantage. Industrial heritage sites are also often accompanied by living memory of local inhabitants, families of workers, etc. Local municipalities may gain socio-economic benefit from industrial heritage tourism, aiding local/regional awareness and memory preservation. Once the site has been declared industrial heritage, its preservation is in the hands of dedicated heritage bodies and therefore managed – in particular financially – in a broader context than the original industrial environment. International heritage bodies also have harmonised guidelines with regard to preservation. For instance, the status of a UNESCO site does not only imply conservation, but also research and education, which also contribute to RK&M.				
Specific issues/ challenges	The local legislation may require the site to be brought back to its original/natural state, which would prevent any initiative aiming at preserving facilities. What may become "heritage", and therefore recorded as such, is not easily pre-defined or controlled. What is considered heritage changes over time, and interpretations of preserved cultural heritage are subject to continuous reinterpretation. Cultural heritage does not assure continued understanding either, as understanding of what was done is based on (future) generations' ability to make sense of today's values and knowledge, which cannot be guaranteed. Furthermore, external factors such as strong urbanisation or, on the contrary, abandonment of the area may, with time, put a strain on industrial heritage (such as pressure to find new uses for the site, or, on the contrary, its abandonment). Using the entire surface infrastructure as an industrial heritage site open for visitors may not be compatible with long-term safety. Accessibility may be limited.				
International dimension	International heritage bodies could become involved, which may give rise to some international awareness and potentially link the site to other similar sites across the world.				
Connection to other approaches/ mechanisms	Culture, Education and Art: Alternative Reuse of the Disposal Site/Infrastructure; Heritage Inventories and Catalogues International Mechanisms: International Inventories and Catalogues; International Treaties, Conventions, Directives Markers: Surface Markers; Monuments				

Mechanism	Industrial heritage
Information resources issued by the RK&M initiative	—
Other information resources	• European Route of Industrial Heritage (ERIH) www.erih.net/ • Publications by the International Committee for the Conservation of the Industrial Heritage (TICCIH) http://ticcih.org/ • Recommendation No. R (90) 20 of the Council of Europe on the protection and conservation of technical, industrial and artworks heritage in Europe https://rm.coe.int/CoERMPublicCommonSearchServices/DisplayDCTMContent?documentId=09000016804e1d18
Examples	• Stripa mine as part of Swedish industrial heritage: see Swedish Industrial Heritage Association www.sim.se/produkter/orebro-lan/stripa-gruva • Industrial sites listed in the European Route of Industrial Heritage www.erih.net/i-want-to-go-there/ • Japan: Sites of Japan's Meiji industrial revolution, Iron & Steel, Shipbuilding and Coal Mining http://whc.unesco.org/en/list/1484 • Spain: Las Medulas www.medulas.com/index.php • Guide to industry In Cumbria, UK www.cumbria-industries.org.uk/

Alternative reuse of the disposal site/infrastructure

Mechanism	Alternative Reuse of the Disposal Site/Infrastructure				
Approach	Culture, Education and Art				
Definition/description	This element refers to (part of) the disposal site and/or its infrastructure being used for a large variety of cultural, natural, recreational and/or educational purposes. It can cover, among others, a nuclear (waste) museum, archive or public information infrastructure established at the disposal site or in its close vicinity. It can also refer to any other cultural purpose (e.g. music hall, artists residence), sports infrastructure (e.g. soccer field), economic activity (e.g. solar energy production systems) or nature preservation. The reuse should make a link to the repository, e.g. at minimum through the name of the building, a commemorative plaque, pictures in the building, etc., but should not affect the safety functions of the repository.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Beneficial reuse by means of creating near- or on-site cultural, natural, recreational and/or educational infrastructures and activities is intended to add value and create interest in the disposal site. Embedding the repository in the local cultural and/or natural infrastructure helps build a sustainable relationship with the host community/region. The cultural and educational infrastructure may be built directly on-site, possibly addressing operational needs during the repository operation; alternatively, historical buildings available in the region, already considered as cultural heritage, may be restored and converted partly for RK&M preservation purposes, e.g. conservation of archives related to the repository. Storytelling, as performed in museums and visitors' centres, additionally contributes to passing on information over generations. To set up a specific educational infrastructure, it may be helpful to call on early retired or retired professionals, with a view to analysing and protecting not only archives but also techniques, know-how and the operation of tools, machines and installations. In the United States, DOE Legacy Management currently focuses on beneficial reuse of legacy sites by means of nature (ecosystem, habitat) preservation, hiking/biking trails, no-cost grazing, hay growing agreements or small timber production, sport infrastructure (e.g. soccer pitches or baseball fields), and solar energy voltaic systems (public/private partnerships). The visitors, ranchers/farmers, sport players or voltaic system operators are encouraged to serve as a local set of "eyes and ears" for natural events, fence breaches, unsafe use of the site, broken signs, etc. Engaging stakeholders and regulators in a decision about the reuse of a site also provides a forum for telling the story of a site and keeping memory alive. Collaboration with universities can also be made, e.g. for studies on landfill evolution over time or for environmental research.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information:	Records:	Knowledge:	Memory: **X**	Awareness:
	The preservation of original infrastructure supports the preservation of memory. Depending on the type of reuse, the element could also aid the transfer and preservation of information, knowledge and some selected records (e.g. in the framework of a museum, dedicated visitor centre or other educational infrastructure).				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail:	
	In case of non-educational and non-repository-oriented infrastructure, low level of detail information (fostering memory) will be provided and preserved. Educational infrastructure would also provide and preserve detailed information.				

Mechanism	Alternative Reuse of the Disposal Site/Infrastructure				
Scope	What is the main geographical or administrative-political scope (development / implementation / operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional: **X**	National:	International:	Virtual:
	Alternative reuse of the site/infrastructure would normally apply at the local and regional level.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term:	Very short term:	
	This mechanism is entirely focused on the medium term.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational:	Pre-closure:	Post-closure: **X**	
	Alternative reuse of the site/infrastructure would normally not be implementable before closure.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done:	Pre-operational: **X**	Operational:	Pre-closure: **X**	Post-closure:
	Alternative reuse of the infrastructure needs to be developed, in the sense of "planned", just before implementation, However, early discussions on future reuse of the site and/or its infrastructure may also be part of a participatory process in the siting phase.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	As a dedicated RK&M preservation mechanism, beneficial reuse is always intentional.				
	Is the mechanism mainly tangible or intangible?				
	Tangible: **X**	Intangible:			
	This mechanism is tangible (the maintained infrastructure), accompanied by intangible aspects (e.g. gatherings, storytelling, etc.)				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission: **X**	Non-mediated transmission:			
	Alternative reuse of the disposal site/infrastructure would work, as an RK&M preservation mechanism, in mediated transmission only.				
Actors	This mechanism will be a joint activity among the implementing agency, the regulator, local government, local communities, local entrepreneurs and professionals in the field of culture, nature, education and/or art. After repository closure, an adequate management structure for maintaining oversight through alternative reuse will need to be set up (public body or private initiative such as a foundation, an association, etc.).				
Main strengths/benefits	Alternative reuse contributes to anchoring the facility in the local community. Local municipalities have socio-economic benefit from alternative reuse, aiding local/regional awareness and memory preservation. It also helps to disseminate information to a large audience. The close geographic connection to the repository can be considered an advantage.				
Specific issues/challenges	The local legislation may require that the site be brought back to its original or natural state, which would prevent any initiative aiming at preserving, adapting or building cultural or educational facilities. If a site is returned to a near-original environmental condition or one with virtually no visual evidence of its past or clues as to its history, this could contribute to loss of memory. The success of this approach partly depends on the responsiveness of the local community. Any new initiative should be sufficiently outstanding to attract wide public interest. For the creation and operation of a museum or a public information facility, resources and an adequate management structures must be secured over many decades. In times of economic shortage, there can be no guarantee that this type of cultural infrastructure will continue to be financed. The right balance should be maintained between activities that are attractive to the general public while conveying useful historical and scientific background information. A permanent aspect of this mechanism is to respect and thereby not affect the safety functions of the repository.				
International dimension	There could be "twinning" co-operations with other reuse sites.				
Connection to other approaches/ mechanisms	Oversight provisions: land use control; monitoring; planning of responsibilities Memory institutions: museums; archives; libraries *(could be established on-site)* Culture, Education & art: industrial heritage; education research & training; Art markers Dedicated record sets and summary files: KIF *(could be included in certain reuse activities)*; SER *(could be archived near/on-site)*				

Mechanism	Alternative Reuse of the Disposal Site/Infrastructure
Information resources issued by the RK&M initiative	• H. Codée E. Verhoef, *What's the story? Using art, stories and cultural heritage to preserve knowledge and memory*. In: NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate, 15-17 September 2014 Verdun*, France, pp. 53-56. OECD, Paris. • D. Shafer, *The DOE Office of Legacy Management. Inviting People in as Opposed to Keeping Them Out: An Alternative Strategy for Knowledge and* • *Memory preservation*. In: NEA (2013), *The Preservation of Records, Knowledge and Memory (RK&M) Across Generation: Improving our Understanding. RK&M Workshop Proceedings 12-13 September 2012 in Issy-les-Moulineaux, France*, pp. 63-65. OECD, Paris. • C. Massart, *Constructing memory through artistic practices: Laboratories*. In: NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate, 15-17 September 2014 Verdun*, France, pp. 125-131. OECD, Paris.
Other information resources	• National Research Council (2003). Long-Term Stewardship of DOE Legacy Waste Sites: A Status Report. Committee on Long-Term Institutional Management of DOE Legacy Waste Sites, Phase II. • U.S. Department of Energy, Office of Legacy Management (2008). Office of Legacy Management, the First Five Years. FY2004-FY2008. • Graham, N., Zook, K., Wilkinson, J. and Pietrzak, A. (2018), Nuclear, Landmarker for a Waste Isolation Site: International Architecture Competition. Waste Management Conference. Phoenix, Arizona, US, WM Symposia. The winner of the 2017 international architecture competition for repository markers for WIPP in the US designed a facility that would be developed at the location of the repository and address current issues (CO_2 sequestration research). This concept is aimed at keeping the location viable to the local community and culture, while changing over time to address generational issues.
Examples	• Various activities at COVRA in the Netherlands: www.covra.nl/ • Interpretive centers (ICs) and nature reserves in the US at Fernald (www.lm.doe.gov/land/sites/oh/fernald_orig/AboutFernald/aboutF.htm) and Weldon Springs (www.lm.doe.gov/weldon/interpretive_center/online_tour/weldon_spring_site_through_the_20th_century.pdf) • Long-term Environment Observatory (OPE-Observatoire pérenne de l'environnement) established by Andra at the Laboratoire de Meuse-Haute-Marne in 2007 (http://meusehautemarne.andra.fr/landra-en-meusehaute-marne/installations/lobservatoire-perenne-de-lenvironnement) • Former nuclear plant in Lucens, now storage area for cultural heritage of Canton Vaud, see www.notrehistoire.ch/medias/61827 • Landesplattenberg Engi in Switzerland, a former slate mine turned into a concert hall (www.plattenberg.ch/) • "Reliving" mining activities in Spain, e.g. at the Pozo Sotón mine (www.visitapozosoton.es/en/tour) and in the UK, e.g. The Big Pit in south Wales.

Heritage inventories and catalogues

Mechanism	Heritage inventories and catalogues
Approach	Culture, Education and Art
Definition/description	Heritage inventories and catalogues are databases and publications that hold heritage related data, references, documents and maps. They can be digital and/or physical and are set up and run by organisations at the international, national or local/regional level. They aim at documenting heritage (both tangible and intangible) for its protection and conservation, but also at raising and maintaining awareness and memory of past activities. Industrial and architectural heritage inventories and catalogues are of particular interest for radioactive waste disposal related RK&M preservation.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Heritage inventories and catalogues generally assist access to and increase awareness of existing information about topical or regional heritage. They often include systematic photographic coverage as well as detailed descriptions, including the precise location of the entries. They can be printed and/or published online and are aimed both at specialists and wider audiences. In the field of RWM, such mechanisms could point to the location of the repository (e.g. in the framework of an inventory of industrial heritage) and/or to other information resources related to the repository (e.g. the KIF). An international inventory or catalogue dedicated to radioactive waste repositories could be developed and/or repositories could be added as a particular domain to existing inventories/catalogues. Heritage inventory mechanisms can also include other, complementary heritage preservation mechanisms. For instance, for a site to be listed as UNESCO world heritage, a scheme needs to be in place for conservation as well as for research and education related to the site. This multiplies the encouragement for RK&M preservation and transfer.

Mechanism	Heritage inventories and catalogues
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?
	Information: **X** | Records: | Knowledge: | Memory: | Awareness: **X**
	A heritage catalogue raises awareness and provides basic information about its objects. Depending on the aim, the intended audience and the level of detail of the inventory/catalogue, it may point to other information resources and practices, and thereby also contribute indirectly to the preservation of records and knowledge.
	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: **X** | High level of detail:
	As "lists" focusing on buildings and objects, heritage inventories and catalogues provide low levels of detail. They may point to other mechanisms with more detailed information.
	What is the main geographical or administrative-political scope (development / implementation / operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: | Regional: **X** | National: **X** | International: **X** | Virtual: **X**
	Inventories are developed at different geographical levels, with online user access playing a significant role.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: | Medium term: **X** | Short term: | Very short term:
	This mechanism targets the post-operational repository phase, while oversight is operating
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: | Operational: **X** | Pre-closure: **X** | Post-closure: **X**
	Disposal sites can be listed in existing inventories/catalogues at any time.
	—
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: **X** | Pre-operational: | Operational: | Pre-closure: | Post-closure:
	Heritage inventories and catalogues already exist. A dedicated, international repository inventory/catalogue could be set up any time.
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled:
	A dedicated repository inventory could be intentionally established. The listing of a repository site in an existing heritage inventory would also happen intentionally, although it may not be entirely under control of those actors responsible for RK&M preservation. Establishing collaborations with heritage organisations can enhance the chances that those responsible for maintaining inventories and catalogues dedicate attention to radioactive waste disposal projects and repositories.
	Is the mechanism mainly tangible or intangible?
	Tangible: **X** | Intangible:
	The inventories and catalogues are tangible. Through the heritage organisations that maintain them and the elements listed, an intangible component is added to this mechanism.
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission:
	Heritage inventories, as presented here, are run by organisations, thus rely on mediated transmission.
Actors	National and regional inventories may be established by a public administration, such as a ministry. They can be also co-ordinated by private bodies such as associations, e.g. local historical societies, but also by virtual communities. They are targeted at both society at large and specialists.
Main strengths/benefits	Inventories and catalogues are well established, useful sources of structured information as they usually aim to be as complete as possible. National and regional heritage organisations provide administrative and financial support that may last well after repository closure.
Specific issues/challenges	What may become "heritage", and therefore recorded as such, is not easily pre-defined or controlled. What is considered heritage changes over time, and interpretations of preserved heritage are subject to continuous reinterpretation. Being listed in a heritage catalogue/inventory does not assure continued understanding either, as understanding of what was done is based on (future) generations' ability to make sense of today's values and knowledge, which cannot be guaranteed. Upkeep of both physical and digital inventories is required.
International dimension	There are numerous examples of international heritage inventories and catalogues (see also "international inventories" under the approach "International mechanisms").

Mechanism	Heritage inventories and catalogues
Connection to other approaches/ mechanisms	International Mechanisms: International Inventories & Catalogues *(broader category, not restricted to heritage)* Repository related Markers, Time Capsules and Dedicated Record Sets and Summary Files can all be listed on heritage inventories and catalogues. The same goes for mechanisms under the approaches Culture, Education and Art and Memory Institutions.
Information resources issued by the RK&M initiative	—
Other information resources	• International Council of Monuments and Sites (ICOMOS): www.icomos.org/fr/ • UNESCO World Heritage (http://whc.unesco.org/) and Memory of the World (http://en.unesco.org/programme/mow) Programmes
Examples	• Swiss Industrial Heritage Inventory: www.industriekultur.ch/ (in German) • Géoportail, a map of national heritage monuments in France: www.geoportail.gouv.fr/donnees/monuments-nationaux (in French) • List of sites of industrial heritage in Flandres : www.industrieelerfgoed.be/sites-per-regio (in Dutch) • Industrial sites listed in the European Route of Industrial Heritage : www.erih.net/i-want-to-go-there/ • The Inventory and Catalogue of the Cultural Heritage of the Church : www.catholicculture.org/culture/library/view.cfm?recnum=2886

Local history societies

Mechanism	Local History Societies				
Approach	Culture, Education and Art				
Definition/description	There are many local historical societies worldwide, often founded and ran by amateur historians. They may form to preserve a local historic building or historic site, local customs and (folk)lore, or to run local museums and historic houses. As such they study and preserve history in a local context and provide informal support for the activities set up and run by institutional heritage and memory organisations.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Waste disposal activities extend over many years and have an impact on the local community. As such, they become part of the local history and may be remembered in publications of local historians or in a local museum. A specific historical society may also be created to remember the disposal facility. An important activity of local history societies is the publication and cataloguing of documents with local historical relevance, e.g. images, newspaper articles, letters, etc. They may also use and reproduce records preserved in local or national archives to reconstruct and preserve local history, thus also adding to redundancy. Another aspect is expressed through historical re-enactment activities and role-games. Such activities include any presentation held for the purpose of re-enacting an event or situation from the past, or of illustrating conduct from a particular time or period in the past (e.g. restaging of battles, but also everyday life, including work life, through the ages, etc.). This mechanism is difficult to implement in a top-down manner, but it can be encouraged e.g. by actively involving the local community (including the employment of local/regional workers and companies in the repository project, visits, events, involvement of local schools, etc.), establishing contacts with history interest groups, regular publications in local media, etc. More generally, it can be encouraged by communication and dialogue (e.g. about the process leading to site selection, the construction, operation and closure, potential incidents, etc.) that tells a story, with local anchoring points to which the population can relate.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records: **X**	Knowledge:	Memory: **X**	Awareness:
	Local history societies target the preservation of memory of past events, thereby preserving information, too. Preservation of some repository records (administrative rather than technical) may be involved, too.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail:	
	Local history is unlikely to preserve detailed technical information, but it could include more or less detailed contextual information (e.g. about siting decisions, particular incidents, etc.).				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional: **X**	National:	International:	Virtual:
	Local history societies operate on a local and regional scale.				

Mechanism	Local History Societies
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: | Medium term: **X** | Short term: **X** | Very short term:
	A local history society may target the medium term, but also covers the later operational phase, i.e. the short term.
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: **X** | Operational: **X** | Pre-closure: **X** | Post-closure:
	Attention can be dedicated to the development and spread of locally relevant information throughout all phases of disposal projects. Genuine information on major repository related events (construction, operation, closure) should, however, be collected at that time, and less material is expected in the post-closure phase.
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: **X** | Pre-operational: | Operational: **X** | Pre-closure: **X** | Post-closure:
	A local history society may already exist. Otherwise, a local history society may be initiated during the operational and pre-closure phases.
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled: **X**
	Communication and dialogue can focus on telling the story of the disposal project and the people involved and contacts and incentives can be made, but the effectiveness and sustainability of local history societies as a RK&M preservation mechanism depends on the interest of local stakeholders.
	Is the mechanism mainly tangible or intangible?
	Tangible: **X** | Intangible: **X**
	It combines both elements.
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission:
	Local history societies operate with mediated transmission.
Actors	Studying local history is typically taken up by interested individuals. It may be co-ordinated at the local, but also regional or even (inter)national level by means of associations and other groups that are often privately organised. Implementing agencies and other formally responsible actors add to the content of the RK&M that local history societies preserve.
Main strengths/benefits	Waste disposal activities extend over many years, involve many people and do not take place in a vacuum. As such, the repository de facto is part of local history. Moreover, siting often is a controversial and thus a publicly debated and publicised issue. Due to this local embedding, it is conceivable that local and personal records, knowledge and memory could survive where larger, more centralised and distant endeavours could fail.
Specific issues/challenges	This mechanism is at least partly dependent on the existence of a local community, and on the interest of individuals and groups and the attitude of the local community towards the repository and more generally towards its past. Many local historical societies existing today are very small, poorly funded, understaffed and non-professional, which may jeopardise their RK&M preservation capacities. It is in the nature of people to recreate the past from the point of view of the present. The reconstruction of the past thus evolves over time and bears dangers of distortion and simplification.
International dimension	Although history societies often operate on a local and regional scale (see above), there may well be international links to towns with similar facilities or through "twinning" activities.
Connection to other approaches/ mechanisms	Culture, education and art: Intangible cultural heritage; alternative reuse of the disposal site/infrastructure; information dissemination activities Memory institutions: museums; archives Dedicated record sets and summary files: KIF *(can be kept by a local history society)* Markers: surface markers; monuments Time Capsules *(can contain local history and be referred to in local history)*
Information resources issued by the RK&M initiative	Van Hove, E. (2012), "Embedding the Past in the Present", in: NEA (2011), *The Preservation of RK&M Across Generations: Scoping the Issue*, Workshop Proceedings, Issy-les-Moulineaux, 11-13 October 2011, p. 37-38, OECD, Paris.
Other information resources	—
Examples	• Nucleus, the Nuclear and Caithness Archive in the UK has many entries related to local history in its collection. See www.highlifehighland.com/nucleus-nuclear-caithness-archives/2816-2/ and www.facebook.com/nucleuscaithnessarchive/photos/ • Directory of local history and allied societies in the UK: www.local-history.co.uk/Groups/ and Cumbria; in particular: www.local-history.co.uk/Groups/cumbria.html • Local history in Flanders: http://herita.be/over-herita/about-herita

Intangible cultural heritage

Mechanism	Intangible cultural heritage				
Approach	Culture, Education and Art				
Definition/description	According to UNESCO's definition, intangible cultural heritage "includes traditions or living expressions inherited from our ancestors and passed on to our descendants, such as oral traditions, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts" (UNESCO Convention for the Safeguarding of Intangible Cultural Heritage).				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	In siting regions, waste disposal activities are part of the local history. Typically, such activities extend over many years and have an impact on the local community. As such, notwithstanding major disruptive events, awareness and memory is likely to last for quite a while in the local community and region, and this can be supported by the organisation of activities and events such as storytelling, commemorations and rituals. These are difficult to implement in a "top-down" manner, but they can be encouraged e.g. by actively involving the local community (including the employment of local/regional workers and companies in the repository project, visits, involvement of local schools, etc.), by organising events and/or establishing contacts with event committees, history interest groups, etc. More generally, it can be encouraged early onwards by dialogue and communication that tells a story, with local anchoring points the population can relate to (e.g. about the process leading to site selection, the construction, operation and closure, potential incidents). Specific rituals may be developed in connection with the disposal site. A connection can e.g. be made with certain documents (e.g. updating the KIF), with a time capsule, or with monitoring activities (e.g. the transfer of monitoring skills and/or the communication of monitoring results at regular intervals). Commemorations may help to recall important milestones or happenings in the history of the site. Recurring events such as festivals may be a less direct way to maintain awareness and memory. A connection to education could be made by for instance linking the repository to research awards. The use of meaningful toponyms can also be seen as an intangible cultural heritage mechanism (e.g. "Waste Lane" or "Radiant Hill").				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information:	Records:	Knowledge:	Memory: **X**	Awareness: **X**
	Concerning repository operations and repositories, intangible cultural heritage supports the preservation of memory and awareness.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail:	
	With respect to repository operations and repositories, cultural heritage would normally be concerned with practices at a limited level of detail.				
	What is the main geographical or administrative-political scope (development/ implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional: **X**	National:	International:	Virtual:
	This element will be implemented and have effect primarily at the local and regional level. However, its development may conceivably take place at the national or even international level (see below "International dimension").				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term:	Very short term:	
	Intangible cultural heritage is likely to reach the medium term.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational: **X**	Pre-closure: **X**	Post-closure: **X**	
	Attention should be dedicated to the collection of technical and societal practices connected with the disposal project throughout the whole operational and early post-closure phases.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done:	Pre-operational:	Operational: **X**	Pre-closure: **X**	Post-closure: **X**
	Here, developing/planning should go hand in hand with, or be immediately preceding, implementation.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional: **X**	Cannot be controlled: **X**		
	While a commemoration, an event or a street name is implemented intentionally, storytelling, traditions and rituals emerge largely unintentionally and cannot be fully controlled – they rather emerge over time.				
	Is the mechanism mainly tangible or intangible?				
	Tangible:	Intangible: **X**			
	Intangible cultural heritage activities can have tangible components in the form of supporting objects. The UNESCO definition also comprises the instruments, goods, objects of art and cultural spaces inherent to intangible cultural heritage.				

Mechanism	Intangible cultural heritage
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission:
	The core of intangible cultural heritage is mediated transmission.
Actors	Intangible cultural heritage mechanisms may be initiated and sustained by a broad number of actors. The local community is an important actor within this mechanism of RK&M preservation. Collectives of multiple local communities hosting a radioactive waste repository across nations could possibly be involved in the development of intangible heritage. There may also be other interest groups (e.g. anthropologists, activists, historians, writers). Learned societies, associations, guilds, clubs – i.e. groups of individuals who voluntarily enter into an agreement to accomplish a purpose – are likely also to play a role.
Main strengths/benefits	Traditions, rituals, commemorations and other recurring events as well as stories, songs and skill practices have a collective and imaginative force to them that could embed the presence of a waste facility in society. They can reach and involve a broad public and as such create a broad base for memory preservation over time.
Specific issues/challenges	Traditions and rituals are difficult to create. They rather emerge over time from common values and a shared sense of cohesion. Indeed, in order to be durable, rituals must be connected with a shared value and concern a group of people, hence the relevance of enduring local communities and/or interest groups. Legends and stories have the potential to survive for many hundreds of years, but they are likely to evolve with time, leading to an uncontrollable distortion of the message/disconnection of the source. The same applies to toponyms. The implementation and normal operation of the repository may also not be "outstanding" or conversely "common" enough to become or remain the subject of intangible cultural heritage.
International dimension	One could think of an international commemoration day, an international meeting/conference between stakeholders of whatever kind every so many years, internationally shared toponyms, perhaps a global network of local rites (e.g. a particular measurement at a particular interval), etc.
Connection to other approaches/ mechanisms	Markers *(may be included in a ritual or commemoration)* Time capsules *(may be included in or give rise to a ritual or commemoration)* Oversight provisions: Monitoring; Planning of Responsibilities Dedicated Record Sets and Summary Files: KIF *(e.g. revisions, collective readings)* Culture, Education and Art: Information dissemination activities; Local History Knowledge Management
Information resources issued by the RK&M initiative	• J.-N. Dumont, *The Role of Rituals*. In: NEA (2013), The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving our Understanding. RK&M Workshop Proceedings, Issy-les-Moulineaux, 12-13 September 2012, p. 75, OECD, Paris. • A. Rose, "The Long Now Foundation: Fostering responsibility in the framework of the next 10,000 years", in NEA (2013), *The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding*, pp. 79-80. OECD, Paris. • H. Codée and E. Verhoef, "Using art, stories and cultural heritage to preserve knowledge and memory", In: NEA (2015). Radioactive Waste Management and Constructing Memory for Future Generations. Proceedings of the International Conference and Debate. 15-17 September 2014, Verdun, p. 55. OECD, Paris.
Other information resources	• UNESCO (2003). The Convention for the Safeguarding of Intangible Cultural Heritage www.unesco.org/new/en/santiago/culture/intangible-heritage/convention-intangible-cultural-heritage/ • Setzman, E. (2014). Preservation of Information and Communication With Future Generations. 40th Annual Waste Management Conference, WM2014. Phoenix (AZ), USA, Waste Management Symposia. Section on "Spreading awareness and promoting discussion". Available online from: www.wmsym.org/archives/2014/papers/14509.pdf
Examples	• HABOG, the storage facility in the Netherlands: rituals connected with light/shade on the storage buildings. See www.covra.nl/ • Proposal for rituals and other intangible heritage in connection with the idea of the Ray Cat, see Section 1.2.2 in the final report of the RK&M initiative and also e.g. the song "Don't Change Color, Kitty" on www.youtube.com/watch?v=g78hZIEqONM • Play about a failed siting process in Vienne (France) : "Village toxique": http://culturebox.francetvinfo.fr/theatre/village-toxique-recit-d-une-revolte-antinucleaire-a-pougne-herisson-38065 **Examples outside of the nuclear field** • Organ/ASLSP (As SLow aS Possible) is a musical piece by John Cage and the subject of one of the longest-lasting musical performances yet undertaken. The performance of the organ version at St. Burchardi church in Halberstadt, Germany began in 2001 and is scheduled to last 639 years, ending in 2640. www.aslsp.org/de. • http://longnow.org/clock/: a clock under construction in a mountain in western Texas that ticks once a year. The century hand advances once every 100 years, and the cuckoo comes out on the millennium. • The Ise Jingu grand shrine in Mie Prefecture, Japan: every 20 years one is built by copying the other while the other one is deconstructed, thereby preserving both the shrine and the skills. This process has endured for over 1300 years already. www.isejingu.or.jp

Education, research and training

Mechanism	Education, research and training				
Approach	Culture, Education and Art				
Definition/description	This mechanism refers to the dissemination and development of information and knowledge on nuclear sciences, (radioactive) waste management and radiation protection at various levels of complexity through (academic) education, research and training. While natural sciences, engineering and medical sciences may come to mind first, RWM also forms a relevant topic within social sciences and humanities and art faculties (e.g. political science, history, philosophy of technology, organisation sciences, cultural studies, etc.). Education, research and training can also focus on RK&M preservation itself, with RWM as a case study.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Higher education in nuclear sciences and waste management, with regard to both technical and social aspects, is crucial for maintaining a level of knowledge sufficient to understand information related to the repository and the decision-making processes leading to and governing the repository. Engaging primary and secondary schools to address the topic of radioactivity at an early stage contributes to a general awareness and understanding of the issue. Information on the existence and location of disposal sites could be added to teaching curricula, potentially including site visits. Dedicated research and training collaborations with universities can be made in connection with the various stages of the lifetime of the waste facility, e.g. for studies on decision making, landfill evolution over time, environmental research, or RK&M preservation itself. Research awards could also be linked to the repository. Education, research and training programmes for local communities could be developed as part of a set of measures supporting local knowledge and "ownership" (including e.g. monitoring).				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records:	Knowledge: **X**	Memory:	Awareness:
	Education, research and training contribute primarily to preserving knowledge that is necessary to properly understand repositories. They can preserve existing information and memory, and develop new information and knowledge.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail: **X**	
	Depending on the target audience, this mechanism covers both high and low levels of detail.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local:	Regional: **X**	National: **X**	International:	Virtual:
	In most countries, education and research are organised on a regional or national level. Besides this, but on a much smaller scale, training may take place on a local or even international level, too. Online formats exist (e.g. MOOCs, Massive Open Online Courses), adding a virtual component to this mechanism.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term: **X**	Very short term: **X**	
	Education, research and training generally target the short term, with training focusing, in particular, on the very short term (the workforce cycle in organisations). Education covering repository basics would be required for ongoing RK&M preservation in the medium term.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure: **X**	
	Education, research and training programmes can be implemented any time, and should be evaluated and fine-tuned regularly during all repository phases.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational:	Operational:	Pre-closure:	Post-closure:
	Education, research and training on radioactivity and RWM, as mechanisms and concepts, readily exist. Their fine-tuning can be considered part of their implementation.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	Governments, implementing agencies and regulators can actively prepare information and educational activities in collaboration with actors responsible for education, research and training on various levels.				
	Is the mechanism mainly tangible or intangible?				
	Tangible:	Intangible: **X**			

Mechanism	Education, research and training	
Characteristics	Research, education and training are in themselves intangible, but supported by tangible devices such as textbooks and tools.	
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?	
	Mediated transmission: **X**	Non-mediated transmission:
	Research, education and training are clear examples of mediated transmission as they are about the transfer of information and knowledge from one generation to the next. Their content is also subject to continuous evolution.	
Actors	Education is typically the responsibility of regional or national governments, but may also be in private hands. Aspects of the curriculum also rely at least in part on individual schools and teachers. In collaboration with "hands-on" stakeholders (implementing agency, regulator, technical support organisations, etc.), researchers from multiple disciplines involved with nuclear science in general and RWM in particular can develop research tracks and information packages and be involved in teaching and training, both in academic and non-academic settings. Recommendations could be issued by international organisations.	
Main strengths/benefits	Knowing, researching and understanding the issues at stake is crucial to ensure the survival of comprehensible messages aimed at future generations. Education, in particular as part of obligatory school curricula, is a powerful way to widely disseminate information and to raise awareness and competence. Research, education and training related to radioactivity, being part of fundamental physics, is likely to survive, if not in relation to energy production then with regard to medical, industrial and/or agricultural applications. Major nuclear events have been and are also likely to remain a topic in various disciplines over time, e.g. in history and social studies of science and technology (STS).	
Specific issues/challenges	Adequate funding must be secured for research, education and training programmes outside the standard school system. Adequate information and skills must be taught. Higher education interest in nuclear issues, being related to professional life, may fade in a post-nuclear energy era.	
International dimension	See the mechanism "International Education & Training Programmes" under the approach "International mechanisms".	
Connection to other approaches/ mechanisms	International Mechanisms: International Education & Training Programmes Culture, Education and Art: Alternative reuse of the disposal site/infrastructure; Information dissemination activities Dedicated Repository Records: KIF *(could be a tool in education)*; SER *(can be used in higher education, research and training)* Oversight Provisions: Monitoring Knowledge Management	
Information resources issued by the RK&M initiative	—	
Other information resources	—	
Examples	• List of nuclear educations and training programmes in the U.S. www.nei.org/advantages/jobs • Education agreement between US DOE and Colorado Mesa University around the Grand Junction, Colorado disposal cell (more info via https://energy.gov/lm/office-legacy-management) • Grimsel Summer School at the Grimsel Test Site (Switzerland) www.grimsel.com/images/GTC_Files/Flyer GTS Summer School 2017.pdf • The play„ Village Toxique", based on the case of the resistance of a French village, in the 1980s against a project of radioactive waste repository. This play is proposed to schools, as an educational tool to argumentation, controversies, in connection with the classical Greek theatre: www.cndp.fr/crdp-reims/fileadmin/documents/preac/culture_theatre_charleville/DP_Village_toxique_01.pdf • LIBRA, a learning and information platform about radioactive waste in the Campine region in Belgium, a collaboration between Thomas More university college, the Belgian radioactive waste management agency (NIRAS/ONDRAF) and the local partnerships around the surface disposal of low- and intermediate-level radioactive waste (MONA and STORA) http://libra.thomasmore.be/ • BNEN, the Belgian Nuclear higher Education Network, with the primary objective to educate young engineers in nuclear engineering and its applications and to develop and maintain high-level nuclear competences in Belgium and abroad. It catalyses networking between academia, research centres, industry and other nuclear stakeholders. http://bnen.sckcen.be/ and www.sckcen.be/en/Education_training/SCKCEN_academy	

Public information dissemination activities

Mechanism	Public information dissemination activities
Approach	Culture, Education and Art
Definition/description	This element generically refers to the dissemination of information on nuclear energy, ionising radiation, RWM and related topics through a large variety of media, including exhibitions, publications (from historical and scientific works to comics), websites, information sessions, documentary films and other media, directed at the general public.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	A large variety of information is available on nuclear energy, ionising radiation and RWM, disseminated via various media (from leaflets to reports to online interviews to documentaries), from various sources (from nuclear lobby to protest groups to open source platforms). Information centres dedicated to radioactivity and/or RWM are often part of radioactive waste disposal projects, then constituting a particular information dissemination activity that links knowledge to the site and supports memory of the disposal facility.
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?
	Information: | Records: | Knowledge: **X** | Memory: | Awareness:
	Public information dissemination activities mainly target the preservation of knowledge about RWM and specific disposal projects for the general public. Information is shared and thereby preserved to a certain, limited degree. Memory of disposal activities may also be supported.
	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: **X** | High level of detail:
	Compared with expert knowledge, the level of detail addressed here is low.
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: **X** | Regional: **X** | National: **X** | International: | Virtual:
	Public information dissemination activities may foster RK&M preservation on the local, regional or national level. Also the organisation of these activities may come from the local, regional or national level.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: | Medium term: | Short term: **X** | Very short term: **X**
	Information dissemination activities are expected to be organised mainly during the (pre-)operational phase. They may continue in the post-closure phase.
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: **X** | Operational: **X** | Pre-closure: | Post-closure:
	For information dissemination activities, the implementation timescale is equal to the target timescale.
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: **X** | Pre-operational: | Operational: | Pre-closure: | Post-closure:
	Public information dissemination activities, as concepts, readily exist. The conceptualisation and planning of individual events can be considered part of their implementation.
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled:
	Organisations formally involved in RWM may organise public information dissemination activities according to a pre-defined information policy that may take RK&M preservation considerations into account. Additionally, other players may use this mechanism according to the topical matters of the moment.
	Is the mechanism mainly tangible or intangible?
	Tangible: **X** | Intangible: **X**
	Information is intangible, but supported by tangible carriers, such as exhibitions, brochures, etc. Either of these may be actively disseminated.
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission:
	Public information dissemination activities are a form of mediated transmission.
Actors	Information dissemination activities can be performed under the responsibility of many different actors: the regulator and implementing agency at the time of repository siting, construction and operation, local/regional/national government, local information committees, other public/private organisations at the local, regional and national level. Information will also be disseminated by actors without a "formal" responsibility, such as documentary makers, protest groups, journalists, workers, researchers, etc.

Mechanism	Public information dissemination activities
Main strengths/benefits	All types of dissemination activities that raise the level of awareness and understanding about RWM in general and disposal projects in particular support RK&M transfer and preservation. Different information dissemination media have different strengths with regard to their scope, impact and longevity. E.g. governmental and scientific publications have the potential to remain accessible over many decades, while videos posted on social media have the potential to reach large groups of people.
Specific issues/challenges	Information must be collected and presented in a way that is appropriate and understandable for the public, and opinions on appropriateness and understandability vary. Technocracy and expertocracy are a challenge, as is polarisation (although for the sake of awareness alone, polarisation might be seen as a benefit). Particular care must be taken to use media and formats that are attractive to young people. The need for simplification may not be compatible with the dissemination of information on complex technical issues.
International dimension	Internet, films, documentaries, international publications, open source media, etc. have international outreach.
Connection to other approaches/ mechanisms	Dedicated repository records: KIF Culture, education and art: alternative reuse of the disposal site/infrastructure; education, research and training; art Regulatory framework: *e.g. regulations related to the right to access to environmental information* Memory institutions: libraries.
Information resources issued by the RK&M initiative	—
Other information resources	Stilgoe, J. & Lock, S. (2014). Why should we promote public engagement with science? *Public Understanding of Science*, 23(1), pp. 4 – 15.
Examples	• Exhibition "De Homer à Oppenheimer", Palais de la Découverte, Paris, 03.12.2013–08.06.2014 www.palais-decouverte.fr/fr/ressources/expositions-passees/la-radioactivite-de-homer-a-oppenheimer-exposition-terminee/ • Hadermann J.; Issler H.; Zurkinden A. (2014): Die nukleare Entsorgung in der Schweiz 1945-2006. Von den Anfängen bis zum Entsorgungsnachweis [Nuclear waste management in Switzerland: From the beginnings to the demonstration of disposal feasibility]. Verlag Neue Zürcher Zeitung NZZ, Zürich (in German) • The Belgian implementing agency NIRAS/ONDRAF publishes a biannual magazine for the broad public and triannual newspaper distributed in the region of the central interim storage facilities. www.niras.be/general-publications

Art

Mechanism	Art				
Approach	Culture, Education and Art				
Definition/description	This broad mechanism includes public art, visual arts (drawing, painting, sculpture, photography, video, filmmaking, internet art), socially engaged art, design, craft, architecture, music, performing arts (dance, theatre) and literature inspired by nuclear (waste) culture.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	The nuclear field has been a source of inspiration for many artists, producing artworks exhibited in public space, museums, preserved in public collections and documented in publications. Art can support RK&M preservation as it can help and stimulate the exploration of speculative futures and the visualisation of the immaterial and invisible (see Carpenter, 2016 and NEA, 2015, pp. 110-136). Works of art may be commissioned to respond to a particular nuclear site, to engage a local community, make public nuclear archives, facilitate interdisciplinary dialogue or convey a particular message. As such, art may relay cultural knowledge, information or awareness from one generation to another or aim to communicate directly to the future. Art competitions can be a useful tool to collect new ideas and provide multiple perspectives on RK&M preservation and RWM. If the proposals are published and archived and the artworks executed and preserved, they also contribute directly to RK&M preservation. A "Percent for Art" scheme can be implemented, where from the start of the project some percentage of the project cost is set aside to fund and install public art.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information:	Records:	Knowledge:	Memory: **X**	Awareness: **X**
	Art contributes to preserving memory and awareness. It also aims to preserve cultural knowledge related to the repository and RWM in general. Artworks themselves, when kept with the appropriate context, can be seen as a record.				

Mechanism	Art
Scope	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: **X** | High level of detail:
	With respect to radioactivity and radioactive waste disposal, art would normally be expected to transmit messages with low levels of detail.
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: | Regional: **X** | National: **X** | International: **X** | Virtual: **X**
	If not connected to a building or monument (cf. the respective mechanisms), art is most often not connected to a site, but could be displayed, performed, etc. at various places. In this sense, art works on a national, international and virtual scale. Museums with permanent exhibitions may have a regional (or even national) influence.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: | Medium term: **X** | Short term: **X** | Very short term:
	Although the focus of art is on the timescale of decades or centuries, it can also address RK&M creation and transfer in the very short term, and its influence may extend to the long term.
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: | Operational: **X** | Pre-closure: **X** | Post-closure:
	The making of individual pieces of art in the repository context may peak in the operational phase. Preliminary work for RK&M preservation purposes, supported before the repository is operated, may be considered as part of the concept development (see hereunder).
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: **X** | Pre-operational: **X** | Operational: **X** | Pre-closure: | Post-closure:
	The concept of Art as a means to foster knowledge and memory already exists. But as a component of a strategy it may still be further developed. The making of individual pieces of art is considered here as implementation (see above).
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled: **X**
	As an intentional RK&M preservation mechanism, works of art may be commissioned, art competitions can be organised and a "Percent for Art" scheme can be implemented. Apart from that, it cannot be controlled.
	Is the mechanism mainly tangible or intangible?
	Tangible: **X** | Intangible: **X**
	This mechanism covers both tangible (e.g. visual arts, literature) and intangible (e.g. performance art, dance) art.
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission: **X**
	Art may operate as mediated transmission relaying cultural knowledge, information or awareness from one generation to another; or as non-mediated transmission producing cultural artefacts and public artworks (e.g. in the form of markers) which intend to communicate a message directly to a future audience.
Actors	Works of art may be commissioned from artists and artist collectives, e.g. by the implementing agency, a museum, public arts organisation, local community or heritage organisation, at a local, regional, national and international level. A dedicated, inter- and transdisciplinary committee could be set up.
Main strengths/benefits	Visual arts are a powerful means for mediation with the public. They can help expand awareness of radioactive waste issues to a large public, and may act as an introduction or a pointer to more specific information. Depending on the type of artwork and media, visual art may document changing perceptions of RWM and bring together academic research and professional knowledge from different disciplines and industrial sectors, engaging diverse parts of the population over many years. Non-linguistic communication avoids the drawbacks associated with languages (translation, obsolescence, etc.), has the potential to deliver complex ideas and messages, and include archive and documentary material. Contemporary visual art is concerned with critical awareness of visual culture, landscape, architecture exploring conceptual and invisible concerns such as radiation and geological disposal. Artists are also experimenting with durable sustainable formats such as distributed online networks, microfiche, land-art, gesso and stone carving.
Specific issues/challenges	Very often, the primary purpose of art is neither to last nor to inform, and artistic freedom is highly valued. Art with the dedicated goal of RK&M preservation should thus preferably be specifically commissioned in partnership with art museums and agencies.

Mechanism	Art
Specific issues/challenges	The level of public engagement, and the message delivered, may vary greatly, and their impact may be experienced many years after production. When the work of art is created to convey a specific message, this message can be very basic ("Danger!") or very complex, such as "the psychic haunting" of radiation. As non-verbal communication is typically vague and imprecise, it allows multiple readings and cannot be completely culture-independent. Art works relying on verbal communication, such as films, poetry or novels, may not be understood after a certain period of time. Works of art placed in the public space serve an aesthetic and symbolic function. They are typically subject to the opinion of the public and may be removed if they no longer correspond to the prevailing taste. They may also become political symbols and be destroyed for that reason. The media, materials and processes used in visual arts have a direct impact on their longevity. For some types of works, such as films, videos or computer art, specific equipment or software is necessary, and needs to be preserved to support the artwork.
International dimension	Art is typically able to deliver messages to an international audience. Various international art platforms exist (e.g. international art festivals).
Connection to other approaches/ mechanisms	Memory Institutions: Museums Culture, Education and Art: Industrial Heritage; Alternative Reuse of the Disposal Site/Infrastructure; Intangible cultural heritage Markers
Information resources issued by the RK&M initiative	• NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations. Proceedings of the International Conference and Debate*, 15-17 September, 2014, Verdun, France. Part III: Contributions from Artists and Posters. pp. 109-136. OECD, Paris. • H. Codée & E. Verhoef, *Using art, stories and cultural heritage to preserve knowledge and memory.* In: NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate - 15-17 September 2014, Verdun, France*, p. 55 (explaining how, in the Netherlands, COVRA collaborates with regional museums by acting as a storage facility for collections that are not on display), OECD, Paris.
Other information resources	• Anderson, K. (2005), Designing for deep time: how art history is used to mark nuclear waste. A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Theory, Criticism and History of Art, Design and Architecture within the joint degree M.S./M.F.A. program School of Art and Design Pratt Institute October 2005. www.kellianderson.com/MSthesis.pdf • http://nuclear.artscatalyst.org/ • Carpenter, E. (Ed.) (2016). The Nuclear Culture Source Book. Black Dog Publishing, London. • Graham, N., Zook, K., Wilkinson, J., Pietrzak, A. (2018). Nuclear, Landmarker for a Waste Isolation Site: International Architecture Competition. WM2018 Conference, Phoenix, Arizona, USA.
Examples	• Markers designed for WIPP (Landscape of Thorns, Menacing earthworks, Spike field, etc.) www.wipp.energy.gov/picsprog/articles/wipp exhibit message to 12,000 a_d.htm • Andra's programme on visual arts e.g. www.andra.fr/memoire-et-art/reglement_appel.pdf • www.cecilemassart.com/ • Films such as "Into Eternity", "Containment", "Journey to the safest place on earth" • Erich Berger and Mari Keto, "Inheritance" http://inheritance-project.net/ • Thomson & Craighead, "Temporary Index". This project is about creating a series of real-time numeric counters expressing radioactive decay. Each display will countdown in seconds, showing the time remaining before the given item of waste or a particular site is considered to be safe. As a first step, data projections have been displayed in art galleries. The next step will be to establish a network of these counters online, which can later be attached to places such as Google Earth. Ultimately, possibilities of building semi-permanent physical counters in the places referred to will be investigated, with a view to making them self (solar) powered. See www.thomson-craighead.net/temporary_index.html • Nuclear Culture project: http://nuclear.artscatalyst.org/ • The Center for Land Use Interpretation: www.clui.org/ • Schemes such as *Percent for Art*: 1% of the total project costs are allocated to the development of public artwork. The advantage of this scheme is that the real costs of artwork are accounted for at the very start of the project, rather than as an additional afterthought. This model could be very valuable for ensuring RK&M is implemented from the start. • Various works held in collections of Contemporary Art: Tate Gallery, UK; Museum of Modern Art, New York; Living Art Museum, Iceland. **Examples of long-term art projects outside of the RWM field** • The Long Now Foundation, established in 1996 to develop the 10,000 Year Clock and Library projects, including a "Rosetta disk" (a nickel disk micro-etched with information in thousands of languages), as well as to become the seed of a very long-term cultural institution. The Long Now Foundation hopes to provide a counterpoint to today's accelerating culture and help make long-term thinking more common. http://longnow.org/ • Jem Finer, Long Player, London. A 1000 yearlong composition, started in 1999, scheduled to end in 2999. https://longplayer.org/ • Organ/ASLSP (As SLow aS Possible). www.aslsp.org/de/

Knowledge management

Knowledge retention tools

Mechanism	Knowledge retention tools
Approach	Knowledge Management
Definition/description	This mechanism refers to a range of explicit activities undertaken to retain knowledge within an organisation or other group of people when one of its members is due to leave through re-location, resignation or retirement. Activities could include an "audience with", the appointment of an apprentice, etc.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Knowledge retention tools contribute directly to RK&M preservation by providing a clear and explicit method for extending the range of people who can benefit from knowledge over time. The retention tools can also help to convert information into usable knowledge. It can be implemented top-down, supported by trained individuals and dedicated programs, or more informally and bottom-up, by volunteers within the organisation, group or project.
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?
	Information: | Records: | Knowledge: **X** | Memory: | Awareness:
	Knowledge retention tools operate explicitly to preserve knowledge. They will also support the preservation of information and can aid the preservation of records (if these are also transferred in the knowledge retention process) and memory (in the sense of broader, contextual information, such as why certain research tracks were started or abandoned, why certain particular pieces of equipment were bought, etc.).
	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: | High level of detail: **X**
	Knowledge retention tools would usually be designed to share and extend access to detailed knowledge, and allow its further development.
	What is the main geographical or administrative-political scope development/implementation/ operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: **X** | Regional: | National: | International: | Virtual: **X**
	Knowledge retention tools are independent of geographical scope; they would rather work within a single organisation or a certain group of experts. This "in-house scope" is identified here as "local" (even though it is not "on-site local"). Besides this, the online/virtual scope may be the most notable one.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: | Medium term: | Short term: **X** | Very short term: **X**
	Realistically it is likely that, in the current formats, knowledge retention tools would not preserve knowledge beyond 100 years.
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: **X** | Operational: **X** | Pre-closure: **X** | Post-closure: **X**
	Knowledge retention tools would be implemented during all the disposal project phases, at least up to closure but preferably also beyond (e.g. to support oversight activities).
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: **X** | Pre-operational: **X** | Operational: **X** | Pre-closure: | Post-closure:
	Knowledge retention tools already exist, but they should be refined and extended for and during disposal projects, also with a view to go beyond short term, operational knowledge needs.
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled:
	Knowledge retention tools need to be implemented intentionally.
	Is the mechanism mainly tangible or intangible?
	Tangible: | Intangible: **X**
	The knowledge retention tools mechanism is essentially intangible, as it is designed to extend knowledge to people. But it will be supported by tangible tools (manuals, equipment, documents, etc.).
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission:
	Knowledge retention is a good example of a mediated transmission mechanism, as it is designed to actively pass on knowledge between individuals, organisations and projects.
Actors	Anyone actor in the field of RWM with knowledge related to disposal projects can apply knowledge retention tools. However, there is a risk that if it is not the responsibility of any specific individual, no-one will take it on. It is therefore important to elaborate knowledge retention responsibilities explicitly, among and/or involving implementing agencies, regulators, research institutes, non-governmental organisations, local community representatives, etc. Knowledge management professionals should be involved - it could be argued that organisations that implement professional methods, such as "Retention of Critical Knowledge" (RoCK), have a much greater chance of successful knowledge retention.

Mechanism	Knowledge retention tools
Main strengths/benefits	Knowledge retention tools are already in practice and are relatively easy to learn, apply and transmit. It allows for knowledge preservation as well as knowledge optimisation and development. As it is a process, there is ample opportunity to ensure that the recipients understand the transmitted knowledge and that ambiguities are avoided. Knowledge management is a blossoming and evolving field, and RWM arguably is a challenging and interesting environment for its further development.
Specific issues/challenges	As knowledge retention relies on the repeated and ongoing application of a human-interaction process, it is vulnerable to change, distortion, selectiveness or abandonment. Triggers for such events can be financial or societal, including political and psychological issues (individual or corporate). These might include carelessness, frustration, envy, time pressure, competition, pride, etc. Knowledge and knowledge retention tools and media evolve rapidly. Current knowledge retention tools focus notably on short-term, operational needs. Where countries are phasing out nuclear energy, the interest in nuclear knowledge may diminish.
International dimension	Knowledge is increasingly becoming global in scale, and knowledge retention tools can be applied virtually. Knowledge retention tools can be adapted to any culture. International applications can build on more localised experiences.
Connection to other approaches/ mechanisms	Knowledge Management: Knowledge risk analysis; Knowledge sharing philosophy Culture, Education and Art: Education, research and training; Industrial heritage; Intangible cultural heritage Oversight Provisions: Monitoring; Clear and planned responsibilities International Mechanisms: International Research, education and training programmes Regulatory Framework: Safeguards.
Information resources issued by the RK&M initiative	• J. Day (2012). *Management of knowledge across generations: preventing knowledge loss, enabling knowledge readiness.* In: NEA (2013), The Preservation of Records, Knowledge and Memory (RK&M) across Generations: Scoping the Issue. Workshop proceedings. The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue. 11-13 October 2011, Issy-les-Moulineaux, France. pp. 73-78. OECD, Paris. • J. Day & E. Kruizinga (2013). *Knowledge retention strategies across generations*. In: NEA (2013), The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. Proceedings of the second RK&M Workshop. The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. 12-13 September 2012, Issy-les-Moulineaux, France pp. 57-61, OECD, Paris.
Other information resources	• IAEA (2011). Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation. Nuclear Energy Series No. NG-T-6.7, IAEA, Vienna. • Heler, D. (2012). Palo Verde Nuclear Generating Station. Knowledge Transfer and Retention (KT&R) Preservation & Program (USA). IAEA - Practical Approaches to Risk Management of Knowledge Loss in Nuclear Organizations. Scientific and Technical Exchange. Sept 26-28, 2012, Gelendzhik (Russia). • Wisbey, S. and Clark, A. (2014). Application of Knowledge Management to the UK's Radioactive Waste Management Programme. Waste Management Conference. Phoenix, Arizona, USA. WM Symposia, US.
Examples	• Shelley, A. (2012). How can we retain the key knowledge our organisations need for future success? Slides that mention examples of good practices according to the author. See www.slideshare.net/Arthur.Shelley/shelley0812-know-retentiontransfer.

Knowledge risk analysis

Mechanism	Knowledge risk analysis				
Approach	Knowledge management				
Definition/description	Knowledge risk analysis refers to a range of explicit activities undertaken to identify, understand and control the risk of knowledge loss from an organisation or other group of people. It can include analysis of business threats, system health checks, and control of staff demographics, such as age profiles, subject matter expertise, etc.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Knowledge risk analysis contributes directly to RK&M preservation by providing a clear and explicit method for identifying and countering threats to its loss. It can also help to (re)convert information into usable knowledge. It can be implemented top-down, supported by trained individuals and dedicated programs, or more informally and bottom-up, by volunteers within the organisation, group or project. Knowledge risk analysis and knowledge retention tools should work together.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information:	Records:	Knowledge: **X**	Memory:	Awareness:
	Knowledge risk analysis operates explicitly to preserve knowledge. It will also support the preservation of information and can also aid the preservation of records (if these are part of the analysis) and memory (in the sense of broader, contextual information, such as why certain research tracks were started or abandoned, why certain particular pieces of equipment were bought, etc.).				

Mechanism	Knowledge risk analysis				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail:				High level of detail: **X**
	A knowledge risk analysis would in itself not preserve a high level of detail, but it generally is applied to and aimed at preserving detailed knowledge.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local: **X**	Regional:	National:	International:	Virtual: **X**
	A knowledge risk analysis is independent of geographical scope; it would rather work within a single organisation or a certain group of experts. This "in-house scope" is identified here as "local" (even though it is not "on-site local"). Besides this, the online/virtual scope may be the most notable one.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term:	Short term: **X**	Very short term: **X**	
	Realistically it is likely that, in the current formats, the knowledge preservation effect of knowledge risk analysis would not apply beyond 100 years.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure:	
	Knowledge risk analysis can be implemented during all the disposal project phases, at least up to closure but preferably also beyond (e.g. to support oversight activities).				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational: **X**	Operational: **X**	Pre-closure:	Post-closure:
	Knowledge risk analyses are carried out already, but should be refined and extended for and during disposal projects, also with a view to go beyond short term, operational knowledge needs.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	Knowledge risk analyses need to be implemented intentionally.				
	Is the mechanism mainly tangible or intangible?				
	Tangible:	Intangible: **X**			
	The knowledge risk analysis mechanism is essentially intangible, as it is a process to identify, understand and control the risk of loss of knowledge held by people. But it will be supported by tangible tools (manuals, equipment, documents, etc.).				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission: **X**	Non-mediated transmission:			
	The knowledge risk analysis is an iterative process designed to avoid knowledge loss over time.				
Actors	Any one actor in the field of RWM with knowledge related to disposal projects can apply a knowledge risk analysis. However, there is a risk that if it is not the responsibility of any specific individual, no-one will take it on. It is therefore important to elaborate knowledge risk analysis responsibilities explicitly, among and/or involving implementing agencies, regulators, research institutes, non-governmental organisations, local community representatives, etc. In these cases it is best to involve knowledge management professionals.				
Main strengths/benefits	Knowledge risk analysis is at the heart of knowledge management and preservation. Dedicated knowledge risk analysis tools are rather well developed and can be learnt, diversely applied and transmitted.				
Specific issues/challenges	As knowledge risk analysis is an iterative process involving human interaction, it is vulnerable to distortion or abandonment. The causes of knowledge loss are also diverse, including material and human aspects which can be unintentional but also deliberate. There can be financial or societal factors at play in knowledge loss, comprising political and even psychological issues. These might include carelessness, time pressure, competition, pride, etc., i.e. issues not always easily addressed. Nevertheless, a knowledge risk analysis needs to be followed up by practicable knowledge retention activities. Knowledge develops and changes over time, so that it may not always be clear which knowledge should be preserved and which may be considered redundant.				
International dimension	The knowledge risk analysis mechanism can be applied equally well in any culture, and international applications can build on more local experiences.				
Connection to other approaches/ mechanisms	Knowledge Management: Knowledge retention tools; Knowledge sharing philosophy Culture, Education and Art: Research, education and training *(the content, target groups, … of which can be informed by knowledge risk analysis)* Dedicated Record Sets and Summary Files: SER (*knowledge risk analysis can inform the SER process)*				

Mechanism	Knowledge risk analysis
Information resources issued by the RK&M initiative	• S. Tunbrant (2012). *Examples of Loss of RK&M and Possible Countermeasures as Received by the Members*. In: NEA (2013), The Preservation of Records, Knowledge and Memory (RK&M) across Generations: Scoping the Issue. Workshop proceedings. The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue. 11-13 October 2011, Issy-les-Moulineaux, France. pp. 47-54. OECD, Paris. • NEA (2014). Preservation of Records, Knowledge and Memory across Generations. Loss of information, records, knowledge and memory in the area of conventional waste disposal. Study prepared in the framework of the NEA Initiative on the Preservation of Records, Knowledge and Memory (RK&M) across Generations. NEA/RWM/R(2014)3. OECD, Paris.
Other information resources	• IAEA (2006). Risk Management of Knowledge Loss in Nuclear Industry Organizations. IAEA, Vienna. • A.Tolstenkov 2012). *Approaches and Methods of Risk Management Including IT Applications (Russia)*. In: IAEA - Practical Approaches to Risk Management of Knowledge Loss in Nuclear Organizations. Scientific and Technical Exchange. Sept. 26-28, 2012, Gelendzhik (Russia). IAEA, Vienna.
Examples	—

Knowledge sharing philosophy

Mechanism	Knowledge sharing philosophy				
Approach	Knowledge management				
Definition/description	A knowledge sharing philosophy refers to a form of ethos of sharing knowledge, within organisations and beyond, delivered via a range of explicit activities. It can include communities of practice, expert directories, expert systems, collaborative software technologies, and knowledge repositories (knowledge bases). The knowledge sharing philosophy sits above the related knowledge retention tools. A developed philosophy should lead to a set of retention tools.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Developing and implementing a knowledge sharing philosophy contributes directly to RK&M preservation by providing a strong ethos and a clear and explicit methodology for extending the range of people who can benefit from and co-develop knowledge. Its focus is not directly on preserving knowledge over time, but the more people hold and contribute to certain knowledge, the more likely it is to be preserved over time. A knowledge sharing philosophy can also help to convert information into usable knowledge. It can be implemented top-down, supported by trained individuals and dedicated programs, or more informally and bottom-up, by volunteers within the organisation, group or project.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information:	Records:	Knowledge: **X**	Memory:	Awareness:
	A knowledge sharing philosophy operates explicitly to share knowledge. It will also support the preservation of information and can aid the preservation of records (if these are also shared) and memory (in the sense of sharing broader, contextual information, such as why certain research tracks were started or abandoned, why certain particular pieces of equipment were bought, etc.).				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail:			High level of detail: **X**	
	A knowledge sharing philosophy would support sharing and extending access to detailed knowledge, and allow its further development.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local:	Regional:	National:	International:	Virtual: **X**
	A knowledge sharing philosophy is independent of geographical scope; it would rather work within a single organisation or a certain group of experts. This "in-house scope" is identified here as "local" (even though it is not "on-site local"). Besides this, the online/virtual scope may be the most notable one.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term:	Short term: **X**	Very short term: **X**	
	Realistically it is likely that, in the current formats, a knowledge sharing philosophy would not preserve knowledge beyond 100 years.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure:	
	A knowledge sharing philosophy should be implemented during all the disposal project phases, at least up to closure but preferably also beyond (e.g. to support oversight activities).				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational: **X**	Operational: **X**	Pre-closure:	Post-closure:
	Knowledge sharing already exists as a driving process, but it should be refined and extended for and throughout disposal projects, also with a view to go beyond short term, operational knowledge needs.				

Mechanism	Knowledge sharing philosophy		
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?		
	Intentional: **X**	Unintentional:	Cannot be controlled:
	A dedicated knowledge sharing philosophy needs to be implemented intentionally.		
	Is the mechanism mainly tangible or intangible?		
	Tangible:	Intangible: **X**	
	A knowledge sharing philosophy is essentially intangible, as it refers to a certain ethos, attitudes and behaviour that should result in the extension of knowledge to people. However, it will be supported by tangible tools (manuals, equipment, documents, etc.).		
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?		
	Mediated transmission: **X**	Non-mediated transmission:	
	This mechanism is a good example of a mediated transmission mechanism, as it is designed to actively share knowledge between individuals, groups and organisations.		
Actors	A knowledge sharing philosophy needs to be cultivated as a form of organisational ethos, so that everybody involved in disposal projects (employees of implanting agencies, regulators, researchers, members of the supply chain, non-governmental organisations, politicians, local community representatives, etc.) has the freedom and encouragement to share their knowledge and be open to that of others, within and beyond their organisations. However, there is a risk that if it is not the dedicated responsibility of any specific individual, no-one will take it on or at least not structurally. It is therefore important to elaborate a knowledge sharing philosophy by means of developing specific knowledge sharing tools and responsibilities. Knowledge management professionals, educational professionals and perhaps also (science) communication experts can help in this regard.		
Main strengths/benefits	Once the mechanism is ingrained in the ethos of an organisation or project more generally, and practised via application of tools, it often self-perpetuates. A knowledge sharing philosophy encourages inter- and trans-disciplinarity, by which, in turn, it encourages learning and communication. The field of knowledge management, which provides tools to deliver a philosophy of knowledge sharing, is blossoming. A knowledge sharing philosophy also fits current trends towards citizens' science and knowledge crowdsourcing.		
Specific issues/challenges	As a knowledge sharing philosophy relies on a certain ethos, on attitudes and behaviour in the form of ongoing human-interaction processes, it is vulnerable to change, distortion, selectiveness or abandonment. Triggers for such events can be financial or societal, including political and psychological issues (individual or corporate). These might include carelessness, frustration, envy, time pressure, competition, pride, etc. Knowledge and knowledge sharing tools and media evolve rapidly. Current knowledge sharing tools typically focus on short-term, operational needs. The technicality of large parts of disposal projects related knowledge may hinder its sharing beyond a limited group of experts, especially in technocratic/expertocratic environments. Some knowledge items within the nuclear field are also restricted (e.g. in the context of dual-use). Where countries are phasing out nuclear energy, the interest in nuclear knowledge may diminish.		
International dimension	A knowledge sharing philosophy can be developed equally well in any culture, although some cultures may find this easier than others. Where relevant, international applications can build on each other's experience.		
Connection to other approaches/ mechanisms	Knowledge Management: Knowledge retention tools; Knowledge risk analysis International Mechanisms: International co-operation; International research, education and training programmes Culture, Education and Art: Research, education and training; Public information dissemination activities; Alternative reuse of the disposal site/infrastructure *(e.g. interactive visitor centres)* Oversight Provisions: Monitoring; Clear and planned responsibilities		
Information resources issued by the RK&M initiative	I. Hill (2013). *NEA Data Bank: Knowledge Preservation Activities*. In: NEA. The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. Proceedings of the second RK&M Workshop. 12-13 September 2012, Issy-les-Moulineaux, France. OECD, Paris.		
Other information resources	• IAEA (2009). Development of Knowledge Portals for Nuclear Power Plants, IAEA Nuclear Energy Series, No. NG-T-6.2. IAEA, Vienna. • M. Skrzeczkowska (2017). *Building understanding – IAEA activities considerable in improvement of radioactive waste and spent fuel management, decommissioning & remediation.* In: Forum on Stakeholders Confidence 18th meeting, IAEA, Vienna, Sept 12-14, 2017. OECD, Paris.		
Examples	The NEA Data Bank, which is designed to be a centre of reference with respect to basic nuclear tools, such as computer codes and nuclear data, used for the analysis and prediction of phenomena in the nuclear field. It should also provide a direct service to its users by developing, improving and validating these tools and making them available as requested. See www.oecd-nea.org/databank/		

Oversight provisions

Monitoring

<table>
<tr><th>Mechanism</th><th colspan="5">Monitoring</th></tr>
<tr><td>Approach</td><td colspan="5">Oversight provisions</td></tr>
<tr><td>Definition/description</td><td colspan="5">The Cambridge English dictionary online defines monitoring as “to watch and check a situation carefully for a period of time in order to discover something about it”. In the context of radioactive waste repositories it can include monitoring of: disposal system performance; environmental parameters; institutional provisions; socio-economic conditions; and agreements made with local hosts and other stakeholders. All these activities contribute to oversight either by “keeping an eye” on the technical system itself, and/or on its interaction with the natural and social environment.</td></tr>
<tr><td>How does this mechanism contribute to RK&M preservation/ How can it be implemented?</td><td colspan="5">While technical experts may understand monitoring to be about performance confirmation and safety case validation, concerned citizens may see it to be more about acknowledging uncertainty and detecting unanticipated problems (Bergmans et al., 2012). In either case, monitoring serves the purpose of RK&M preservation by collecting, interpreting and keeping data on a continuous basis.
Oversight can be exercised through monitoring of technical parameters and through technical analyses of those data (notably: repository containment function, environmental and health impact). Oversight can also be exercised through monitoring of institutional provisions (e.g. land use control). Additionally, oversight can be exercised, in a broader sense, through monitoring socio-economic developments and the agreements made with the local hosts and other stakeholders. Monitoring may thus well be useful for reasons beyond radiological protection, too.
Depending on the wishes of local communities, active participation by members of civil society in the technical monitoring of activities may be encouraged, e.g. by offering training which could also include the engagement to pass on monitoring skills to future generations. In any case societal feedback mechanisms on monitoring results should be organised, contributing to knowledge and memory preservation.
While the ad hoc results of monitoring have their own relevance, monitoring above all is about “follow-up” over time. In this sense, monitoring both necessitates and enables RK&M preservation, as it requires and involves the collection, preservation and (re)interpretation of information and the transfer of knowledge to do so.
In summary, provided that suitable technical solutions are developed, the near-field, far-field, institutional and socio-economic environment of the repository could be monitored over time and various actors can be involved. RK&M preservation itself can also be monitored.</td></tr>
<tr><td rowspan="8">Scope</td><td colspan="5">Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?</td></tr>
<tr><td>Information: X</td><td>Records: X</td><td>Knowledge: X</td><td>Memory:</td><td>Awareness:</td></tr>
<tr><td colspan="5">Monitoring creates and transfers information and records (for comparison over time). It preserves knowledge through the act of monitoring itself and the evaluation of information it generates. It also supports the preservation of memory and awareness.</td></tr>
<tr><td colspan="5">What is the level of detail addressed/provided by the mechanism?</td></tr>
<tr><td colspan="3">Low level of detail:</td><td colspan="2">High level of detail: X</td></tr>
<tr><td colspan="5">Monitoring programmes are designed to generate and manage large amounts of data.</td></tr>
<tr><td colspan="5">What is the main geographical or administrative-political scope (development/implementation/ operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation?</td></tr>
<tr><td>Local: X</td><td>Regional:</td><td>National:</td><td>International:</td><td>Virtual:</td></tr>
<tr><td colspan="5">The act of monitoring the repository and its direct environment is local. Monitoring broader environmental, health and socio-economic environment of the repository and RK&M preservation itself will also imply the regional and national level. Monitoring can also be part of national research programmes and international collaborations, and monitoring results are more and more often shared and made accessible online.</td></tr>
<tr><td rowspan="4">Timescales</td><td colspan="5">Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term:</td><td>Medium term: X</td><td>Short term: X</td><td colspan="2">Very short term:</td></tr>
<tr><td colspan="5">Monitoring projects are typically developed and intended primarily for the short term, but they can be aimed to continue (in an adapted form) in the medium term, e.g. technical barrier system monitoring (if remote technology is available), host formation monitoring, environmental monitoring on surface, monitoring of institutional/administrative provisions, and/or monitoring of the implementation of other measures and agreements (including those related to RK&M preservation itself).</td></tr>
<tr><td colspan="5">When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td colspan="2">Pre-operational: X</td><td>Operational: X</td><td>Pre-closure: X</td><td>Post-closure: X</td></tr>
</table>

<table>
<tr><th>Mechanism</th><th>Monitoring</th></tr>
<tr><td rowspan="5">Timescales</td><td>Monitoring should start when the siting procedure begins, e.g. related to collecting baseline data.
The operational phase is likely to be the most intense phase of monitoring, including system implementation and performance monitoring, administrative (compliance) monitoring, environmental monitoring and socio-economic monitoring.
Due to technical restrictions (avoiding impairment of containment function of the disposal system, instrumentation durability, etc.), monitoring may be focused on environmental, health, institutional and socio-economic monitoring in the medium term.
In Switzerland post-closure monitoring should continue “as long as it is thought beneficial to society” and in the United States, for the WIPP facility, the monitoring programme should last until “no more meaningful data are being collected”.</td></tr>
<tr><td>When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: | Pre-operational: X | Operational: X | Pre-closure: X | Post-closure:</td></tr>
<tr><td>Repository monitoring in general is relatively well developed. Specific concept development and planning for monitoring needs to be done during the pre-operational and the operational phase, both technically and socially, e.g. deciding on monitoring programmes preferably in dialogue with affected stakeholders, developing and installing technologies, collecting baseline conditions, setting out means for continued participation. Monitoring needs to be continuously developed, in accordance with disposal project evolutions, technological (equipment) and social (actors, arrangements) developments, and monitoring results.</td></tr>
<tr><td rowspan="8">Characteristics</td><td>Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td>Intentional: X | Unintentional: | Cannot be controlled:</td></tr>
<tr><td>Although informal monitoring may also take place (e.g. visiting citizens carrying a Geiger counter), it is the organised monitoring over time (be it by agencies or non-governmental organisations) that contributes mainly to RK&M preservation across generations.</td></tr>
<tr><td>Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td>Tangible: X | Intangible: X</td></tr>
<tr><td>Monitoring involves both tangible (records, equipment, the “things” to be monitored, etc.) and intangible components (measuring activities, data processing, virtual monitoring communities, annual/decennial gatherings/commemorations when monitoring results are communicated, etc.).</td></tr>
<tr><td>Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td>Mediated transmission: X | Non-mediated transmission:</td></tr>
<tr><td>Monitoring is an ongoing activity, focused on follow up over time.</td></tr>
<tr><td>Actors</td><td>Implementing agencies, regulators, policy makers, governmental bodies, researchers, environmental groups, local communities, visiting citizens, … may all be variously engaged in monitoring activities ranging from monitoring of the facility, the environment, the health of surrounding populations, accountability, the legitimacy of land use, etc.
Before closure and likely also for a certain period after closure, the implementing agency is responsible for monitoring the system performance under supervision by the regulatory agencies and society at large (local communities, government, parliament, etc.). Responsibilities for “who does what” well after closure have not yet been defined. It is recommended that actors that are not formally responsible should be involved from the early days, such as local communities, interest groups and specialists. The process of participatory reflection on (long-term) monitoring may already help different stakeholders to grasp its meaning and engage the community in discussing their role and expectations in monitoring and preserving RK&M. Although monitoring is understood, in technical circles, as referring to the collection of technical data, there may be parameters that are not strictly technical or that may be technical, but the measurement of which is carried out by players other than the implementing agency.</td></tr>
<tr><td>Main strengths/benefits</td><td>Due to a wealth of stakeholder inputs, monitoring is both popular and quite well developed already. The impact of a repository on environment and health is a broadly shared concern that is likely to last as long as awareness of the repository exists. Monitoring has a strong potential to connect/combine technical and social actors, technical and social information and technical and social activities. As such, it has large potential to be networked into society, which supports RK&M preservation.</td></tr>
<tr><td>Specific issues/challenges</td><td>Post-closure in-situ monitoring is subject to technical restrictions (e.g. avoiding impairment of the safety function of the disposal system, durability of instrumentation, calibration) that may create tensions with social demands. For example, direct monitoring of the post-closure evolution of the engineered barriers demands the development of non-intrusive monitoring techniques, which might be a challenge.
In order for monitoring to continue after closure, institutions and stakeholders other than those who formulated relevant regulation and operated the facility will need to become involved, and financing needs to be arranged. Other challenges may be the organisation of feedback mechanisms of monitoring results and the development of response plans in case monitoring results indicate action needs to be taken. While these issues (response plans, transfer of responsibilities, financing) need to be planned well in advance, they have received limited attention up until now.
If monitoring does not lead to any significant results, interest may be lost over time.</td></tr>
</table>

Mechanism	Monitoring
International dimension	International RK&M preservation dimensions of monitoring can relate e.g. to guidelines and best practices, or international comparison of monitoring data among international nuclear, geological, environmental agencies or interest groups. Monitoring could be subject to regular reporting under international conventions. Virtual sharing of monitoring data across the world could also take place, for instance as citizens' science initiatives.
Connection to other approaches/ mechanisms	Oversight Provisions: Land use control; Clear and planned responsibilities Regulatory Framework: Safeguards (*Safeguards are a particular case of monitoring, required as long as the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is in force);* National regulatory framework *(including e.g. periodic review of monitoring arrangements and measures)* Culture, education and art: Education, research and training *(e.g. involving universities in a variety of research related to monitoring [results]);* Intangible cultural heritage *(e.g. by coupling (the evaluation of) monitoring (data) to a reoccurring event);* Alternative reuse of the disposal site/infrastructure *(e.g. allowing visitors to do measurements/read real-time monitoring results, creating a monitored wildlife reserve, etc.)* Memory institutions: Archives *(e.g. transferring recorded monitoring results)* International mechanisms: International archiving initiatives; International regulations and agreements; International standards and guidelines; International co-operation; International education and training programmes Dedicated record sets and summary files: SER
Information resources issued by the RK&M initiative	• Pescatore, C., Nachmilner, L., Martell, M., Mays, C (2013). Oversight of a Deep Geological Repository and the Role of Monitoring – Some preliminary findings within the RK&M Project of the NEA. MODERN conference, Luxembourg, 18-21 March 2013. • NEA (2014), Monitoring of Geological Disposal Facilities – Technical and Societal Aspects. RK&M project study, NEA/RWM/R(2014)2. • NEA (2013), The Preservation of Records, Knowledge and Memory (RK&M) Across Generation: Improving Our Understanding. RK&M Workshop Proceedings 12-13 September 2012. Items 6, 7 and 8. OECD, Paris. • NEA (2014), 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. • Schneider, T. (2012), Preservation of RK&M for Long Term Storage Facilities: The Results of a French Study In : The Preservation of RK&M Across Generations: Scoping the Issue. Workshop Proceedings, Issy-les-Moulineaux, 11-13 October 2011, pp. 106 – 107. OECD, Paris.
Other information resources	• Bergmans, A., Elam, M., Simmons, P., Sundqvist, G. (2012). Perspectives on Radioactive Waste Repository Monitoring Confirmation, Compliance, Confidence Building, and Societal VigilanceTechnikfolgenabschätzung – Theorie und Praxis 21. Jg., Heft 3, December 2012. • European Commission (2004). Final Report of the Thematic Network on the Role of Monitoring in a Phased Approach to Geological Disposal of Radioactive Waste (EUR 21025 EN). EC, Brussels. • International Atomic Energy Agency (2014). Monitoring and Surveillance of Radioactive Waste Disposal Facilities. Specific Safety Guide No. SSG-31. IAEA, Vienna. • European project Monitoring Developments for Safe Repository Operation and Staged Closure (Modern), www.modern-fp7.eu/ and www.modern2020.eu/
Examples	• France: Long-term Environmental Observatory (Andra) (www.andra.fr/ope/index.php?lang=en) • Canada: First Nations/Aboriginal Nuclear Waste Monitoring Agency (www.nwmo.ca/en/A-Safe-Approach/About-the-Project/Working-in-Partnership/Engaging-With-People/Aboriginal-Engagement) • USA: Community Environmental Monitoring Program (CEMP) around the Nevada Test Site (https://cemp.dri.edu) and Carlsbad Environmental Monitoring and Research Center (CEMRC) of the New Mexico State University around the WIPP site (www.cemrc.org) • Hungary: Social Monitoring and Information Association (TEIT) in connection to the interim storage for spent fuel at Paks NPP and the Local Public Control and Information Association (TETT) linked to the low- and intermediate-level waste respository at Bátaapáti (see www.oecd.org/nea/partnering-for-long-term-management-of-radioactive-waste-9789264083707-en.htm, p.59 and following) • Safecast, a global citizen science project putting environmental data and data collection know-how in the hands of people worldwide (https://blog.safecast.org).

Land use control

Mechanism	Land use control				
Approach	Oversight provisions				
Definition/description	In the context of radioactive waste repositories, land use control refers to specifications and controls on how the land in the vicinity of the repository can or should (cannot or should not) be used. It is conducted by setting a protection zone including the footprint of the disposal facility and its surroundings, in order to reduce the possibility of inadvertent human actions affecting the repository as much as possible. It can refer simply to land use restrictions by prohibiting specific acts, both above and below ground (such as housing, underground excavation, mining and borehole drilling, etc.). But it can also include site reuse plans aimed to help ensure the repository function stays intact and is remembered.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Land use control serves the preservation of RK&M concerning what the land was used for, why the control was established and what the potential risks are within the controlled area. Land use control may also help to sustain on-site, tangible RK&M preservation mechanisms, such as markers. It is advisable for land use controls to involve administrative specifications, site specific records, some form of oversight compliance, and also some form of physical indication on site (e.g. fences, signs). It is important to engage stakeholders in a decision about reuse of the controlled area and the implementation thereof, so that it contributes to disseminating knowledge and memory and enhancing oversight. Developing a site (re)use plan that is beneficial to (local) people is recommended, in the hope that an appropriate and valued reuse of the site will restrict RK&M loss and thus make inadvertent and/or uninformed intrusion less likely.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory or awareness?				
	Information: **X**	Records:	Knowledge:	Memory: **X**	Awareness: **X**
	The implementation of land use control preserves awareness of the existence of the repository and – depending on its content and context – also information and memory. Land use controls are usually also recorded and such records will also preserve information about the reason for the controls.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail:	
	Land use control, prohibiting specific acts and encouraging others, helps raise awareness and memory, thereby preserving basic information. Related records will likely contain more detailed information.				
	What is the main geographical or administrative-political scope (development / implementation / operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation?				
	Local: **X**	Regional:	National:	International:	Virtual:
	Land use control is basically applied to a fixed zone, including the disposal facilities and their surroundings. Beneficial reuse of sites may also benefit people beyond the local level and thus help spread awareness and memory on a broader scope. Accordance needs to be sought with the national regulatory framework.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term:	Very short term:	
	As an oversight provision, land use control will contribute to RK&M preservation in the short term, but is ultimately aimed at the medium term, to avoid inadvertent intrusion after closure.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational:	Operational:	Pre-closure:	Post-closure: **X**	
	Land use control will de facto be implemented as soon as the disposal site is selected. As an oversight provision that contributes to RK&M preservation over time, dedicated land use control needs to be implemented immediately after regulatory closure.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done:	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure:
	Examples of land use control exist, for nuclear as well as non-nuclear sites. Discussing land use control as an oversight provision can be part of a participatory siting procedure and is an ongoing process. Specific preparations for post-closure land use control need to be made during the pre-closure phase, both technically and socially, e.g. determining the area for which the land use control will be implemented, deciding on the condition of physical provisions such as signs and markers preferably in dialogue with affected stakeholders, setting out means for continued participation, etc. The process of participatory reflecting on land use control may already help different stakeholders to understand why the land use control is established and engage the stakeholders in discussing their role and expectations with regard to the reuse plan.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		

Mechanism	Land use control	
Characteristics	Although it is not certain that land use control will continue for hundreds of years after closure, its development and implementation should be carried out intentionally according to the national/regional/local regulation and local context.	
	Is the mechanism mainly tangible or intangible?	
	Tangible: **X**	Intangible: **X**
	It is advisable for land use controls to involve both tangible and intangible elements, such as records containing administrative specifications and site specifications, physical indications on site (e.g. fences, signs) and oversight actions (e.g. checking compliance, maintaining signs, monitoring).	
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?	
	Mediated transmission: **X**	Non-mediated transmission:
	Land use control is an ongoing process.	
Actors	Before closure, the implementing agency – where it owns the land – is responsible for implementing land use control following the guidelines and under the supervision of the regulating agencies. Where the implementing agency does not own the land, responsibilities are with, or defined by, the authorities. Responsibilities for "who does what" after closure have not yet been defined. Likely, any restrictions on land use after closure will be decided by the authorities in consultation with different stakeholders (e.g. local communities, interest groups and specialists).	
Main strengths/benefits	Land use control is a beneficial component of a RK&M preservation strategy due to its regulatory efficacy and societal involvement, especially if land use control involves beneficial reuse (e.g. sports and recreation, biodiversity, agreements with local farmers, solar or wind energy parks) linked to the repository (e.g. by information panels, monitoring, name references); see also mechanism "alternative reuse of the disposal site/infrastructure".	
Specific issues/challenges	The sustainability of the agreed-upon land use control constitutes a challenge. If land use controls are not administratively, physically and societally anchored, they will fall into oblivion/be ignored. In order for land use control to continue after closure, administrative specifications and financing needs to be arranged. Land use control needs to be flexible over time to remain appreciated by stakeholders, while also remaining appropriate, in order to avoid a situation in which a reuse agreement made today becomes invalid for future generations and the site becomes developed in a way that may cause risks. Although long-term land use control may be introduced legally, current regulatory frameworks concern themselves primarily with the short term.	
International dimension	International dimensions of land use control could be related to conventions, directives, guidelines and best practices.	
Connection to other approaches/ mechanisms	Oversight Provisions: Clear and planned responsibilities; Monitoring Culture, Education and Art: Alternative reuse of the site and/or its infrastructure; Public dissemination activities *(can inform about and explain land use control)* Regulatory Framework: National regulatory framework; Safeguards Markers: Monuments; Surface markers; Sub-surface markers Dedicated record sets and summary files: SER; KIF *(can inform about and explain land use control)*	
Information resources issued by the RK&M initiative	• Different sections in NEA (2015). Radioactive Waste Management and Constructing Memory for Future Generations. Proceedings of the International Conference and Debate. 15-17 September 2014, Verdun, France, pp. 43-47, 57-61, 65-70, 143-144, OECD, Paris. • Shafer, D. (2013). *The DOE Office of Legacy Management.* In: The Preservation of Records, Knowledge and Memory (RK&M) Across Generation: Improving our Understanding. RK&M Workshop Proceedings 12-13 September 2012, Issy-les-Moulineaux, France, NEA/RWM/R(2013)3, p. 63. OECD, Paris.	
Other information resources	The US Department of Energy Office of Legacy Management (www.lm.doe.gov)	
Examples	National cadastres and legislation on spatial and land use planning	

Clear and planned responsibilities

<table>
<tr><th>Mechanism</th><th colspan="5">Clear and Planned Responsibilities</th></tr>
<tr><td>Approach</td><td colspan="5">Oversight provisions</td></tr>
<tr><td>Definition/description</td><td colspan="5">This RK&M preservation mechanism is about proactively planning the clear description and transparent assignment of responsibilities for a disposal facility throughout its lifetime, including RK&M preservation. The focus is on the possible changing or moving of responsibilities from the original responsible actors (the implementing agency, the regulating agencies) to other competent actors after closure of the disposal facility, or after the license termination of the disposal project.
Details of what these responsibilities comprise depend on the disposal facility under consideration, its broader societal context and national regulation. They may generally be described as “managing, operating and keeping oversight” over the facility before closure, and “managing and keeping oversight” over the facility after closure. Responsibilities include the duty of providing and preserving information relevant to the disposal facility (before and after closure) and caring for its passive safety after closure.</td></tr>
<tr><td>How does this mechanism contribute to RK&M preservation/ How can it be implemented?</td><td colspan="5">Clear and planned responsibilities serve the purpose of RK&M preservation in two ways. Firstly, through assigning clear and transparent responsibilities for a disposal facility – including for RK&M preservation – to one or more organisations, both in the pre-closure and in the post-closure phases, accountability is established and maintained over time. This minimises the risk of RK&M losses through negligence. It also enables public scrutiny, for society to “keep an eye” on the actual implementation of plans and decisions. As societal oversight, this provides additional support to RK&M preservation. Secondly, it explicitly addresses the finding that the risk of losing RK&M is very high when projects end and/or when responsibilities are transferred to other bodies (NEA, 2014). Careful planning can limit potential losses of RK&M by setting up a timely process of RK&M transfer whereby maximal RK&M preservation is in the interest of both the original responsible organisation and its successor(s).
This mechanism thus is an RK&M preservation mechanism in itself, but also an important support to other mechanisms, e.g. – depending on the chosen national RK&M preservation strategy – laying down the responsibilities for the development and preservation of a SER and KIF, for post-closure monitoring, for developing and implementing a marker, etc.
In order to avoid a responsibility vacuum and accompanying RK&M loss, it is advisable to establish a regulatory and governmental framework relating to how responsibilities for managing the disposal facility – including managing RK&M preservation – are assigned, clearly and transparently communicated and transferred over time.</td></tr>
<tr><td rowspan="8">Scope</td><td colspan="5">Does the mechanism mainly preserve information, records, knowledge, memory or awareness?</td></tr>
<tr><td>Information: X</td><td>Records: X</td><td>Knowledge: X</td><td>Memory: X</td><td>Awareness:</td></tr>
<tr><td colspan="5">The uninterrupted responsibility for the proper functioning of the repository, including oversight, leads to the preservation (and production) of information, records and knowledge. This mechanism thus indirectly supports the preservation of information, records and knowledge and, in their wake, memory.</td></tr>
<tr><td colspan="5">What is the level of detail addressed/provided by the mechanism?</td></tr>
<tr><td colspan="2">Low level of detail:</td><td colspan="3">High level of detail: X</td></tr>
<tr><td colspan="5">This mechanism indirectly supports the preservation of detailed information and knowledge. Depending on the disposal system, on national regulation and on societal demands, the sort of knowledge and the required levels of detail that should be preserved to carry out the responsibility for the proper functioning of the repository may evolve over time. Depending on the specific elaboration of responsibilities for actual RK&M preservation, the focus will be on both awareness/basic information (e.g. a marker) and on knowledge/detailed information (e.g. a SER).</td></tr>
<tr><td colspan="5">What is the main geographical or administrative-political scope (development / implementation / operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation?</td></tr>
<tr><td>Local: X</td><td>Regional: X</td><td>National: X</td><td>International:</td><td>Virtual:</td></tr>
<tr><td colspan="5">The ultimate responsibility for the repository, including RK&M preservation and oversight, lies with the state and the national government. Hence, the planning and assignment of these responsibilities to organisations, potentially including the establishment of a regulatory and governmental framework, is a national task which, according to subsidiarity, may involve regional and local actors. Local, regional and international actors, public and private, can all contribute to developing and taking oversight and RK&M preservation responsibilities and/or to verifying their implementation. The mechanism can thus enable RK&M preservation on all levels involved.</td></tr>
<tr><td rowspan="3">Timescales</td><td colspan="5">Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term:</td><td>Medium term: X</td><td>Short term: X</td><td>Very short term:</td></tr>
<tr><td colspan="5">The planning of responsibilities in the RK&M preservation context addresses the short and medium term, and aims to avoid a transition into the long term (i.e. loss of oversight). Planning, stipulating and designating responsibilities for oversight over a disposal facility and RK&M preservation related tasks urges attention and reflection on these topics, and as such contributes also to the very short term.
Clear responsibilities for managing and keeping oversight over the facility after closure are necessary for a successful transition phase from operational to closure and post-closure activities (i.e. a transition phase in which no RK&M are lost). Clear responsibilities in the operational phase are necessary in view of the overall RK&M preservation strategy, since developing and implementing many of the RK&M preservation mechanisms (SER, monitoring, information dissemination activities, etc.) take place during this phase.</td></tr>
</table>

Mechanism	Clear and Planned Responsibilities				
Timescales	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure: **X**	
	For this mechanism, the implementation timescale refers to the question of when to do the planning and assignment of responsibilities and of how to maintain a clear designation of responsibilities. The planning of responsibilities for the short term (as explained in the previous field) needs to be implemented in the pre-operational and operational phase, while the planning for the medium term needs to be implemented in the late operational and pre-closure phase. Maintaining clear designation of responsibilities is relevant over all timescales, including the post-closure phase.				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational: **X**	Operational: **X**	Pre-closure:	Post-closure:
	Developing the planning of responsibilities to look after the repository and to preserve RK&M should be done in the early disposal project development phase. One should not expect actors that were never involved in RWM to suddenly take on wide responsibilities in this area. The efficacy of responsibilities needs to be monitored over time and adjusted according to disposal project phases and the evolving societal contexts.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	Responsibilities need to be carefully prepared and intentionally planned. One should not expect actors that were never involved in RWM to suddenly take on wide responsibilities in this area. Nevertheless, there is also a level of uncontrollability with regard to who does what in the future.				
	Is the mechanism mainly tangible or intangible?				
	Tangible:	Intangible: **X**			
	The planning and implementation of responsibilities are intangible.				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission: **X**	Non-mediated transmission:			
	Responsibilities need to be transferred from one generation to the next.				
Actors	The ultimate responsibility for the repository, including RK&M preservation and oversight, lies with the state and the national government. Hence, the planning and assignment of these responsibilities to organisations, potentially including the establishment of a regulatory and governmental framework, is a national task. Clear and planned responsibilities should ensure that host communities will not be left "on their own" after closure. This is not to say that local, regional and international actors, public and private, cannot and should not contribute to developing and taking up oversight and RK&M preservation responsibilities and/or to verifying their implementation. It depends on the agreements made, which therefore should preferably be done in a participatory manner even though the responsibility lies with the state. Subsidiarity needs to be discussed. And one should not expect actors that were never involved in RWM to suddenly take on wide responsibilities in this area. Sharing responsibilities for RK&M preservation among more than one actor and in more than one location is recommended to support robustness and redundancy.				
Main strengths/benefits	Planning, stipulating and designating clear responsibilities is a key condition for a functional systemic strategy of RK&M preservation. It forces alertness and reflection on the topic of RK&M preservation and can aid societal awareness. Planning post-closure responsibilities in the operational phase helps to master the short- to medium-term transition period, which is particularly vulnerable with respect to RK&M loss. The regulatory efficacy and societal involvement and approval of this mechanism add to its strength.				
Specific issues/challenges	Loss of records and memory often takes place during transitions of responsibility between organisations. Although the assignment of responsibilities would ideally be introduced in a legal manner, current regulatory frameworks concern themselves primarily with the short term only. Responsibilities for who does what after closure have not yet been formally discussed in many countries. Transfer of responsibilities to other oversight bodies or agencies is usually covered at a basic level only. The operational phase is long and dynamic. Ongoing attention is required to plan and maintain fair and functional responsibilities. Thereby, the need for clear responsibilities in the operational phase itself should not be underestimated. While the "who" question of clear responsibilities may appear to be decided, addressing the "what" question may reveal that tasks related to (the preparation of long-term) RK&M preservation are yet to be defined. The sustainable exercise of responsibilities and the availability of budgets in the future is dependent on the continued willingness of society to keep oversight over the facility.				
International dimension	International RK&M dimensions of clear and planned responsibilities can be related to international conventions, directives, guidelines and best practices.				

Mechanism	Clear and Planned Responsibilities
Connection to other approaches/ mechanisms	Regulatory Framework: National regulatory framework Knowledge Management: Knowledge retention tools *This mechanism is connected to all approaches and mechanisms of a nationally chosen RK&M preservation strategy, through its relation to those who hold the responsibility over them.*
Information resources issued by the RK&M initiative	NEA (2014). Preservation of Records, Knowledge and Memory across Generations. Loss of information, records, knowledge and memory in the area of conventional waste disposal. Study prepared in the framework of the NEA Initiative on the Preservation of Records, Knowledge and Memory (RK&M) across Generations, NEA/RWM/R(2014)3.
Other information resources	—
Examples	The US Department of Energy Office of Legacy Management (www.lm.doe.gov) is the responsibility holder for legacy sites in the United States. The transition of responsibilities from the operator to the Office of Legacy Management is organised by law.

International mechanisms

International regulations and agreements

Mechanism	International regulations and agreements				
Approach	International mechanisms				
Definition/description	This mechanism includes international treaties, conventions, directives, agreements, guidelines and recommendations that greatly vary in scope and objectives and may be implemented between individual countries or within a given group of countries (e.g. IAEA member states, European Community). The voluntary involvement of contracting parties to join the individual mechanisms for a common goal and their declaration of adhesion to the objectives constitute the driving force of various international instruments. Typically, these mechanisms lay down a legislative, regulatory and/or organisational framework and include principles to guide national policies.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	International regulations and agreements play a key role in increasing contracting parties' awareness on the issues at stake and sustaining the common goal identified. Of particular interest for RK&M preservation purposes are mechanisms in the fields of RWM, but also of environmental protection, spatial planning, access to information and heritage preservation. This includes, in particular, multi-level governance mechanisms that operate under the umbrella of an international organisation with voluntary involvement of actors located at different territorial levels (local, national and international, e.g. Aarhus Convention and UNESCO World Heritage Convention).				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records: **X**	Knowledge:	Memory:	Awareness: **X**
	Regulations and agreements are laid down in records. In itself they preserve only a limited level of information. But they constitute a general framework that supports the prevention of loss of RK&M in general. More specifically, their provisions may request the availability of information and the preservation of, at least, a certain level of administrative awareness. Their provisions may also request the production of dedicated records (such as reports written in fulfilment of a directive or agreement).				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail: **X**	
	The level of detail depends on the concrete content and application of the mechanism: some apply to detailed information (e.g. safeguards), some leave this more open (e.g. the 2011 EU Directive on the responsible and safe management of spent fuel and radioactive waste).				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local:	Regional:	National:	International: **X**	Virtual:
	The mechanism can involve actors and activities located at different levels: always international and, as counterparts quite frequently, national.				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term: **X**	Very short term:	
	International regulations and recommendations have different lifespans. Depending on their field of application, they can be expected to remain in force as long as the field of application exists and there is a minimum level of international socio-political continuity.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure: **X**	

<table>
<tr><th>Mechanism</th><th colspan="5">International regulations and agreements</th></tr>
<tr><td rowspan="4">Timescales.</td><td colspan="5">For international regulations and agreements, implementation refers to the application of measures and activities on the appropriate (national/international) level. International regulations and agreements are already being implemented and it is expected that this will continue.</td></tr>
<tr><td colspan="5">When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: X</td><td>Pre-operational:</td><td>Operational: X</td><td>Pre-closure:</td><td>Post-closure:</td></tr>
<tr><td colspan="5">For international regulations and agreements, development refers to the development of the international treaty as such (time of international negotiations). International regulations and agreements relevant to RWM and repositories already exists. Whether it would be beneficial, for the goal of RK&M preservation of radioactive waste repositories, to negotiate new and dedicated ones, needs to be discussed.</td></tr>
<tr><td rowspan="8">Characteristics</td><td colspan="5">Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td colspan="2">Intentional: X</td><td colspan="2">Unintentional:</td><td>Cannot be controlled:</td></tr>
<tr><td colspan="5">International regulations and agreements need to be developed and implemented intentionally.</td></tr>
<tr><td colspan="5">Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td colspan="2">Tangible: X</td><td colspan="3">Intangible: X</td></tr>
<tr><td colspan="5">International regulations and agreements involve both tangible (e.g. the recorded regulations and agreements themselves, the regulatory required records) and intangible elements (e.g. meetings related to discussing their implementation, the staff employed by international organisations, compliance mechanisms).</td></tr>
<tr><td colspan="5">Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td colspan="3">Mediated transmission: X</td><td colspan="2">Non-mediated transmission:</td></tr>
<tr><td colspan="5">Regulations and agreements need to remain administratively and societally anchored and functional in order to be effective. They are under continuous development and need to be transferred from one generation to the next.</td></tr>
<tr><td>Actors</td><td colspan="5">International regulations and agreements are established at the level of international bodies such as the IAEA, UNESCO or the EU or between individual states. However, individual countries or organisations (e.g. EU member states or signatories of the Joint Convention) are responsible for their implementation. Apart from the nuclear regulator, regulatory agencies involved in the fields of environmental protection, spatial planning, safety, security, heritage preservation and archiving are also relevant actors for the development of and compliance with this mechanism. The implementation of regulations and agreements involves all actors formally involved in repository projects and RK&M preservation more broadly (implementing agencies, archives, civil servants, etc.).</td></tr>
<tr><td>Main strengths/benefits</td><td colspan="5">International regulations and agreements offer a common framework at the international level that is generally beneficial for RK&M preservation. As an additional goal, the outcome of such agreements is often a tangible product – a common inventory outline, common standards or periodic reporting in a common format, a shared generic decision-making structure – which, in turn, facilitate information exchange, collaboration, standardisation of practices and support national regulations.
Various international regulations and agreements may address RK&M preservation, which can add to redundancy.</td></tr>
<tr><td>Specific issues/challenges</td><td colspan="5">Depending on their specific nature, these mechanisms may be more or less binding for individual countries and therefore may or may not be transposed and implemented at the national level. Instruments to check compliance and efficacy may not exist.
Their efficacy can be limited in case of conflict or economic, social or environmental crisis. They can indeed be abandoned, perhaps not to be re-established.
The successful development and, later, implementation of international regulations and agreements depends on the willingness of the parties involved (governments, international and national bodies) to cooperate and reach compromises.
Since RK&M preservation has a high degree of context-dependency, it is a challenge for international regulations and agreements to reach a balance between being “too vague” and “too detailed”.</td></tr>
<tr><td>International dimension</td><td colspan="5">The international nature is inherent to this mechanism.</td></tr>
<tr><td>Connection to other approaches/ mechanisms</td><td colspan="5">International Mechanisms: International inventories & catalogues: some conventions (e.g. World Heritage Convention) aim at compiling international inventories (e.g. the “World Heritage List”); International standards; International co-operation; International archiving initiatives
Regulatory Framework: National regulatory framework (depending on their specific nature, international regulations and agreements are integrated in national legislation, either partly or in full); Safeguards</td></tr>
</table>

Mechanism	International regulations and agreements
Information resources issued by the RK&M initiative	• T. Schneider and C. Reaud (2013), *Supranational Mechanisms to support Records, Knowledge and Memory Preservation over the medium term.* In NEA, The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. Proceedings of the second RK&M Workshop. The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. 12-13 September 2012, Issy-les-Moulineaux, France, pp. 71-75, OECD, Paris. • NEA (2015), International Mechanisms to Support Records, Knowledge and Memory Preservation Over the Short and Medium Term. Study prepared in the framework of the NEA Initiative on the Preservation of Records, Knowledge and Memory (RK&M) across Generations. NEA/RWM/R(2015)2.
Other information resources	—
Examples	• UNESCO – World Heritage Convention http://whc.unesco.org/en/conventiontext/ • UNECE – Espoo Convention www.unece.org/fileadmin/DAM/env/eia/Publications/2015/ECE.MP.EIA.21_Convention_on_Environmental_Impact_Assessment.pdf • UNECE – Aarhus Convention www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf • United Nations: The Treaty of Non-Proliferation of Nuclear Weapon (NTP) www.un.org/disarmament/wmd/nuclear/npt/text • Convention for the Protection of the marine Environment of the North-East Atlantic (OSPAR Convention) www.ospar.org/convention/text • IAEA – Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management www.iaea.org/sites/default/files/infcirc546.pdf • EU – Directive 2011/70 EURATOM establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011L0070 • EC – Directive Establishing An Infrastructure For Spatial Information In The European Community (Inspire) http://inspire.ec.europa.eu/index.cfm/pageid/48 • Council of Europe, Committee of Ministers – Recommendation No. R (90) 20 on the protection and conservation of technical, industrial and artworks heritage in Europe https://rm.coe.int/CoERMPublicCommonSearchServices/DisplayDCTMContent?documentId=09000016804e1d18 • UNESCO – The Hague Convention of 1954 for the Protection of Cultural Property in the Event of Armed Conflict www.icrc.org/ihl/INTRO/400 • Nizhny Tagil Charter for Industrial Heritage www.icomos.org/18thapril/2006/nizhny-tagil-charter-e.pdf

International standards and guidelines

Mechanism	International Standards and Guidelines				
Approach	International mechanisms				
Definition/description	This mechanism refers to internationally agreed standards and guidelines as well as recommendations of international organisations that are relevant to one or more aspects of RK&M preservation.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	International standards may be used at various levels of RK&M preservation, such as archiving or spatial information. The IAEA has developed widely accepted safety principles that underpin much of the work performed in the field of RWM. Their application is supported by a system of peer reviews. Specific initiatives, such as the NEA RepMet data model, aim at standardising the description of a particular process. Other initiatives have published guidelines related to more social aspects, such as the NEA FSC, which focuses on stakeholder involvement. These initiatives have the potential to facilitate information exchange and collaboration between waste management programmes and beyond. While international standards and guidelines will not preserve RK&M directly, they can create a favourable framework for RK&M preservation by describing best practices and/or encouraging a harmonised content in a compact form, under the umbrella of an international organisation.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records: **X**	Knowledge: **X**	Memory:	Awareness:
	International standards and guidelines do not directly preserve RK&M, but they constitute a general framework that contributes to RK&M preservation (e.g. by providing standards related to findability or information structuring, by fostering information exchange, etc.)				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail: **X**	
	The level of detail depends on the specific content and application of the international standard/guideline, so it can span both.				

<table>
<tr><th>Mechanism</th><th colspan="5">International Standards and Guidelines</th></tr>
<tr><td rowspan="3"></td><td colspan="5">What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation?
[Note also the field “International dimension” further below.]</td></tr>
<tr><td>Local:</td><td>Regional:</td><td>National:</td><td>International: X</td><td>Virtual:</td></tr>
<tr><td colspan="5">The mechanism can involve actors and activities located at different levels: always international and, as counterparts quite frequently, national.</td></tr>
<tr><td rowspan="10">Timescales</td><td colspan="5">Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term:</td><td>Medium term: X</td><td>Short term: X</td><td colspan="2">Very short term: X</td></tr>
<tr><td colspan="5">Depending on the level of international socio-political continuity and on their field of application, international standards and guidelines typically have lifetimes that do not go beyond 100 years. But they may also be developed to address RK&M preservation for the medium term, e.g. related to oversight.</td></tr>
<tr><td colspan="5">When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational: X</td><td>Operational: X</td><td>Pre-closure: X</td><td colspan="2">Post-closure: X</td></tr>
<tr><td colspan="5">For international standards and guidelines, implementation refers to the application of measures and activities on the appropriate (national/international) level. International standards and guidelines are already being implemented and it is expected that this will continue.</td></tr>
<tr><td colspan="5">When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: X</td><td>Pre-operational:</td><td>Operational: X</td><td>Pre-closure:</td><td>Post-closure:</td></tr>
<tr><td colspan="5">For international standards and guidelines, development refers to the development of the standard/guideline. International standards and guidelines relevant to RWM already exist. Whether it would be beneficial, for the goal of RK&M preservation of radioactive waste repositories, to negotiate new and dedicated ones, needs to be discussed.</td></tr>
<tr><td rowspan="9">Characteristics</td><td colspan="5">Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td colspan="2">Intentional: X</td><td colspan="2">Unintentional:</td><td>Cannot be controlled:</td></tr>
<tr><td colspan="5">International standards and guidelines need to be developed and implemented intentionally.</td></tr>
<tr><td colspan="5">Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td colspan="2">Tangible: X</td><td colspan="3">Intangible: X</td></tr>
<tr><td colspan="5">International standards and guidelines involve both tangible (e.g. the recorded standards and guidelines themselves, but also the results of the application of such standards and guidelines, e.g. in the form of reports, waste inventories, etc.) and intangible elements (e.g. meetings related to discussing their development and implementation and their practical application throughout processes).</td></tr>
<tr><td colspan="5">Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td colspan="2">Mediated transmission: X</td><td colspan="3">Non-mediated transmission:</td></tr>
<tr><td colspan="5">International standards and guidelines need to remain administratively and societally anchored and functional in order to be effective. They are under continuous development and need to be transferred from one generation to the next.</td></tr>
<tr><td>Actors</td><td colspan="5">Widely used standards are developed by interested parties such as organisations, companies or agencies. The work is organised through international agencies such as the International Standards Organisation (ISO) or the European Union. In the nuclear field, the IAEA has published numerous guidelines. Specific standards or guidelines may also be developed in the framework of international co-operation.
Standards and guidelines can be used by the organisation/actors in charge of/involved with the corresponding RK&M activity.</td></tr>
<tr><td>Main strengths/benefits</td><td colspan="5">International standards, guidelines and recommendations generally contribute to RK&M preservation through the harmonisation and the dissemination of best practices. As an additional goal, the outcome is often a tangible product – a common inventory outline, periodic reporting in a common format, a shared generic decision-making structure, a standardised set of essential records – which, in turn, facilitate information exchange, collaboration and also understandability of information over time.</td></tr>
<tr><td>Specific issues/challenges</td><td colspan="5">International guidelines and recommendations are not as binding as international standards and therefore not as widely used.
Instruments to check compliance and efficacy may not exist.
The successful development and, later, implementation of international standards and guidelines may depend not only on the existence of corresponding regulatory instruments, but also on the willingness of the parties involved to cooperate and reach compromises.
Since RK&M preservation has a high degree of context-dependency, it is a challenge for international standards and guidelines to reach a balance between being “too vague” and “too detailed”.</td></tr>
</table>

Mechanism	International Standards and Guidelines
International dimension	The international nature is inherent to this element.
Connection to other approaches/ mechanisms	International standards or at least guidelines or recommendations can be developed for all approaches, whether related to (minimum) content (e.g. Dedicated Record Sets and Summary Files; Time capsules), form (e.g. Markers; Archives *(e.g. ISO standards for record management)* or process (e.g. Culture, Education and Art: Alternative reuse of the disposal site/infrastructure; Oversight Provisions: Monitoring).
Information resources issued by the RK&M initiative	—
Other information resources	The NEA RepMet Initiative, see www.oecd-nea.org/rwm/igsc/repmet/
Examples	Development: • ISO Standards on Information Management, Records Management and Archiving, e.g. ISO 15489-1:2016 - Information and documentation – Records management, see www.iso.org/standard/62542.html • IAEA Safety Standards Series, see www-pub.iaea.org/books/IAEABooks/Series/33/Safety-Standards-Series • NEA: Common Inventorying and Reporting Methodology recently developed by the EGIRM expert group, see www.oecd-nea.org/rwm/pubs/2017/7371-spent-fuel-strategies.pdf Implementation: • Use of archival standards by an implementing organisation to comply with the national archives' requirements

International inventories and catalogues

Mechanism	International Inventories and Catalogues				
Approach	International mechanisms				
Definition/description	This mechanism corresponds to a subset of the information resources that are set up and run by international organisations, such as UNESCO or the IAEA. Inventories and catalogues often take the form of large databases that hold data, references, information, maps, documents and sometimes records. They can have a topical focus (e.g. nuclear science and its applications) or a wide scope (e.g. academic research papers in general). They can be digital and/or physical.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	International inventories and catalogues commonly aim at documenting a certain topic or domain, to be a source of reference, to keep an overview over time, for its protection and/or conservation, but also to raise and maintain awareness (and more rarely memory) about it. International inventories and catalogues also generally assist access to information on a particular topic or domain, and, also depending on their content and format, can also support the development and preservation of knowledge to a certain degree. Repository related data, references and information (including locations) can be added to existing international inventories and catalogues, or dedicated ones can be developed. The potential for a dedicated international catalogue of repository projects should be discussed.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records:	Knowledge:	Memory:	Awareness: **X**
	The focus of international inventories or catalogues is on making accessible and preserving information (actual information and/or via references to other sources), and often they have a topical awareness preservation function. They can also support, to some degree, knowledge preservation (when they offer e.g. codes, procedures, comparative datasets, interactive fora) and preserve some records.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail: **X**			High level of detail: **X**	
	As "lists", international inventories and catalogues may not offer the highest levels of detail, but they are good mechanisms to point to other mechanisms with more detailed information. Some international inventories and catalogues do however have a high level of detail (e.g. spent fuel inventories, certain databanks and platforms).				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local:	Regional:	National:	International: **X**	Virtual: **X**
	Depending on the international inventory or catalogue and on its access policy, the geographical/administrative scope is of limited relevance and its main (RK&M preservation) functioning is online/virtual.				

<table>
<tr><th>Mechanism</th><th colspan="5">International Inventories and Catalogues</th></tr>
<tr><td rowspan="11">Timescales</td><td colspan="5">Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term:</td><td>Medium term: X</td><td>Short term: X</td><td colspan="2">Very short term:</td></tr>
<tr><td colspan="5">Inventories and catalogues can be seen as mainly aimed at the short and medium term, but their preservation function may continue in the long term.</td></tr>
<tr><td colspan="5">When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational: X</td><td>Operational: X</td><td>Pre-closure:</td><td colspan="2">Post-closure:</td></tr>
<tr><td colspan="5">Repository projects can be listed in existing (respective) inventories/catalogues at any time, but should preferably be listed as soon as the repository comes into existence.</td></tr>
<tr><td colspan="5">When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: X</td><td>Pre-operational: X</td><td>Operational: X</td><td>Pre-closure:</td><td>Post-closure:</td></tr>
<tr><td colspan="5">International inventories and catalogues already exist. The development of a dedicated, international repository inventory or catalogue can start as of today.</td></tr>
<tr><td rowspan="9">Characteristics</td><td colspan="5">Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td>Intentional: X</td><td>Unintentional:</td><td colspan="3">Cannot be controlled:</td></tr>
<tr><td colspan="5">A dedicated repository inventory of repository related data could be intentionally established. The listing of data in existing inventories and catalogues would also be intentional.</td></tr>
<tr><td colspan="5">Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td>Tangible: X</td><td colspan="4">Intangible:</td></tr>
<tr><td colspan="5">The inventories and catalogues are tangible. The organisations that develop and maintain them add an intangible component to this mechanism. Some are also accompanied by discussion fora and can link users.</td></tr>
<tr><td colspan="5">Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td colspan="2">Mediated transmission: X</td><td colspan="3">Non-mediated transmission:</td></tr>
<tr><td colspan="5">International inventories and catalogues are a living information resource that is updated and maintained.</td></tr>
<tr><td>Actors</td><td colspan="5">International inventories are often established by international agencies. In this case, input is delivered by a network of national corresponding organisations and relies on voluntary involvement.
Outside of the RWM field, there are also examples of private initiatives, such as Google Books.
They can be targeted at specialists and/or society at large.</td></tr>
<tr><td>Main strengths/benefits</td><td colspan="5">Inventories and catalogues are well established and widely used sources of structured information.
The international scope ensures that information is recorded and stored and helps the inventories to survive the possible evolution of national borders.
They provide an RK&M preservation mechanism that functions well within a systemic approach as they have the capacity to provide links between different mechanisms.
Dedicated international organisations often provide technical and administrative support.</td></tr>
<tr><td>Specific issues/challenges</td><td colspan="5">Completeness and accuracy/reliability of information as well as ease of use are challenging criteria that apply to inventories and catalogues in general.
The long-term sustainability of the actions required to maintain inventories and catalogues can also constitute a challenge. Depending on funding mechanisms, the effectiveness of financial support may vary with the willingness or the capacity of individual states or actors to provide specific funds over the short- and medium-term.</td></tr>
<tr><td>International dimension</td><td colspan="5">The international nature is inherent to this element.</td></tr>
<tr><td>Connection to other approaches/ mechanisms</td><td colspan="5">Culture, Education and Art: Heritage inventories and catalogues
Memory Institutions: Libraries (international inventories holding documents may serve an electronic library function)
Regulatory Framework: Safeguards (inventories of fissile material, though with restricted access)
International Mechanisms: International Archives (archival collections usually include a catalogue as a point of access)
Culture, Education and Art;
Markers;
Time Capsules;
Dedicated Record Sets and Summary Files;
Oversight Provisions
: the mechanisms under all these approaches can be listed and referenced in international inventories and catalogues</td></tr>
</table>

Mechanism	International Inventories and Catalogues
Information resources issued by the RK&M initiative	• J. Schröder and A. Sneyers (2013). *INIS and its national implementation*. In: NEA. The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. Proceedings of the second RK&M Workshop. The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. 12-13 September 2012, Issy-les-Moulineaux, France, pp. 88-90. OECD, Paris. • I. Hill (2013). *NEA Data Bank: Knowledge Preservation Activities*. In: NEA. The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. Proceedings of the second RK&M Workshop. 12-13 September 2012, Issy-les-Moulineaux, France, pp. 91-95. OECD, Paris. • J. Springer, *UNESCO's Memory of the World Programme*. In: NEA (2013). The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. Proceedings of the second RK&M Workshop. 12-13 September 2012, Issy-les-Moulineaux, France, pp. 87-88. OECD, Paris.
Other information resources	—
Examples	• UNESCO – Memory of the World Programme, see www.unesco.org/new/en/communication-and-information/flagship-project-activities/memory-of-the-world/homepage/ • The IAEA Online Information Resource for Radioactive Waste Management, see https://newmdb.iaea.org/ • The IAEA International Nuclear Information System (INIS), see www.iaea.org/inis/ • NEA Databank, see www.oecd-nea.org/databank/ • European Route of Industrial Heritage, see www.erih.net/ • Academia.edu, an online platform for academics to share research papers. See www.academia.edu/ • The International Time Capsule Society (ITCS) in Atlanta USA provides a registry of time capsules around the world, making sure that they are properly recorded. They provide a free online registration form for anyone wishing to register a time capsule. https://crypt.oglethorpe.edu/international-time-capsule-society/ • Global maps featuring repositories could be made, comparable to the ones existing today featuring e.g. nuclear power plants, such as www.nuklearforum.ch/de/nuclearplanet/app

International co-operation

Mechanism	International co-operation				
Approach	International mechanisms				
Definition/description	This mechanism refers to co-operative activities among multiple nations on economic, social, cultural, humanitarian and technological issues (and differences), that are co-ordinated at the international level. In the field of RWM, international co-operation can e.g. take the form of common research programmes or projects, discussion platforms, international working groups on specific topics, peer reviews or international conferences.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	International co-operation in the field of RWM serves the dissemination, joint development and preservation notably of information and knowledge, but also of records (e.g. reports being developed, shared and preserved internationally). It can contribute to RD&D on both technical and social strategies, including RK&M preservation. It can also serve awareness about, and memory of, repository projects worldwide. This element is particularly useful in the very short and short term.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records:	Knowledge: **X**	Memory:	Awareness:
	International co-operation in the field of RWM serves the preservation notably of information and knowledge.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail:			High level of detail: **X**	
	International co-operation usually addresses and provides a high level of detail.				
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local:	Regional:	National:	International: **X**	Virtual:
	The mechanism involves actors and activities located at different levels: international and, as counterparts most often, national (but local or regional also possible).				

Mechanism	International co-operation				
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?				
	Long term:	Medium term: **X**	Short term: **X**	Very short term: **X**	
	Current forms of international co-operation traditionally aim at the very short and short term. Co-operation to target the medium term (i.e. prior to loss of oversight) has been pursued with the RK&M initiative.				
	When should this mechanism be implemented? This may or may not be equal to the target timescale.				
	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure: **X**	
	International co-operation can take place during all stages of repository projects, including the post-closure phase in the context of oversight (e.g. international monitoring projects, which remain to be developed).				
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.				
	Done: **X**	Pre-operational: **X**	Operational: **X**	Pre-closure: **X**	Post-closure:
	International co-operation already takes place (e.g. through IAEA, NEA, the European Commission (including committees such as ENSREG as well as IGD-TP and European Joint Programming), EDRAM and international non-governmental organisations). With a view to RK&M preservation, existing programmes can be further developed and/or new ones established, preferably through the pre-operational and operational phases of repository projects. International oversight co-operation could also still be (further) developed in the pre-closure phase.				
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?				
	Intentional: **X**	Unintentional:	Cannot be controlled:		
	International co-operation needs to be developed and implemented intentionally.				
	Is the mechanism mainly tangible or intangible?				
	Tangible:	Intangible: **X**			
	International co-operation among nations and people is intangible, but supported by tangible media such as reports, websites, conference proceedings, experiments, technologies, etc.				
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?				
	Mediated transmission: **X**	Non-mediated transmission:			
	Co-operation is a clear form of mediated RK&M preservation.				
Actors	RWM related international co-operation may be established within a political, economic or legal framework such as the European Community and the Euratom Treaty, or by international agencies such as the IAEA, the NEA, Greenpeace International, etc. It may also be set up by individual organisations and supported by collaboration agreements (such as implementing agencies (e.g. EDRAM), regulators (e.g. ENSREG), municipalities with nuclear facilities [GMF]). International co-operation can also be established through more citizen driven initiatives (e.g. Safecast). The objectives, conditions and means for expanding the co-operation are defined by the relevant organisation.				
Main strengths/benefits	Approaching RK&M preservation through international co-operation is advisable in light of the long timeframes (including the respective fluidity of national boundaries) and an internationally shared concern for protecting humans and the environment and informing future generations. It adds to redundancy in relation to more national RK&M preservation mechanisms. It has clear strengths and benefits related to both content and practice (peer review, exchange of best practices, development of expertise, joint implementation of preservation actions, periodic reporting, etc.). These values are notably focused on the short term, but can expand into the medium term, also in relation to oversight activities. In view of its transboundary nature, international co-operation is well established in the nuclear field in general. The experience is that if international organisations co-ordinate co-operation efforts, they often provide important technical and administrative support.				
Specific issues/challenges	RK&M preservation has a high degree of context-dependency and thus a balance needs to be found between national/local specificity and international relevance. The implementation of multi-level responsibility and decision making depends on the willingness of the partners at various territorial levels to reach compromises. The efficiency of international projects and working groups often relies on voluntary contributions. Continuity may be an issue.				
International dimension	The international nature is inherent to this mechanism.				

Mechanism	International co-operation
Connection to other approaches/ mechanisms	International Mechanisms *(all international mechanisms rely on international co-operation)* Regulatory Framework: Safeguards Dedicated Record Sets and Summary Files; Memory Institutions; Markers; Time Capsules; Culture, Education and Art; Oversight Provisions: *: all the mechanisms under all these approaches can, to a larger of smaller extend, be part of/benefit from international co-operation (see also the field "International dimension" in the different mechanism description sheets)*
Information resources issued by the RK&M initiative	• Schneider, T. and C. Reaud (2013), "Supranational Mechanisms to support Records, Knowledge and Memory Preservation over the medium term", in *The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding – Proceedings of the second RK&M Workshop*, 12-13 September 2012, Issy-les-Moulineaux, France, pp. 71-75. • NEA (2015), "International Mechanisms to Support Records, Knowledge and Memory Preservation Over the Short and Medium Term", Study prepared in the framework of the NEA Initiative on the Preservation of Records, Knowledge and Memory (RK&M) across Generations, NEA/RWM/R(2015)2.
Other information resources	—
Examples	• IAEA International Nuclear Safety Group (INSAG), see www.iaea.org/topics/nuclear-safety-and-security/committees/insag • Various IAEA projects such as GEOSAF (see www-ns.iaea.org/projects/geosaf/) or HIDRA (see www-ns.iaea.org/projects/hidra/) • NEA Radioactive waste management Committee (RWMC) and corresponding initiatives (such as the RK&M initiative), projects and working groups, see www.oecd-nea.org/rwm/ • Implementing Geological Disposal of radioactive waste Technology Platform, see https://igdtp.eu/ • EU Joint Programming, see https://ec.europa.eu/europeaid/policies/eu-approach-aid-effectiveness/joint-programming_en • EU Framework Programme for Research and Innovation, see www.eda.europa.eu/procurement-biz/information/codeda-regulationaba/eu-framework-programme-for-research-and-innovation • The European Nuclear Safety Regulators Group (ENSREG), see www.ensreg.eu/ • The International Association for Environmentally Safe Disposal of Radioactive Material (EDRAM), an association of organisations with responsibility for management of radioactive waste in their respective countries, see www.edram.info/index.php?id=249 • Group of European Municipalities with nuclear Facilities (GMF), see www.gmfeurope.org/ • Greenpeace International, see www.greenpeace.org/international/ • Safecast, an international, volunteer-centered organisation devoted to open citizen science for the environment, see https://blog.safecast.org/about/

International education and training programmes

Mechanism	International Education and Training Programmes
Approach	International mechanisms
Definition/description	This mechanism is about dedicated international higher education and training programmes in the broad field of RWM, contributing to the capacity building of the various stakeholders, sometimes with a specific focus on the development of local expertise (e.g. IAEA programmes). It can cover topics belonging to the natural sciences and engineering, to the social sciences and humanities, but also RK&M preservation itself.
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	Education and training in nuclear sciences and waste management, with regard to both technical and social aspects, is crucial for maintaining a level of knowledge sufficient to develop, maintain and understand information related to the repository and the decision-making processes leading to and governing the repository. International programmes can support the education and training of local experts and the framework for mobilising pluralistic expertise. These are key elements to foster knowledge sharing and ultimately knowledge continuity. International programmes also foster mutual understanding across borders and, to a certain degree, international co-operation.

Mechanism	International Education and Training Programmes
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?
	Information: | Records: | Knowledge: **X** | Memory: | Awareness:
	Education and training focuses on knowledge development and preservation. Indirectly, they contribute to the preservation of information and memory related to disposal projects.
	What is the level of detail addressed/provided by the mechanism?
	Low level of detail: | High level of detail: **X**
	International education and training programmes usually cover high levels of detail.
	What is the main geographical or administrative-political scope (development/implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]
	Local: | Regional: | National: | International: **X** | Virtual:
	Online formats exist (e.g. MOOCs, Massive Open Online Courses), adding a virtual component to the generally international scope of this mechanism.
Timescales	Which timescale(s) is this mechanism mainly aimed at (target timescale)?
	Long term: | Medium term: | Short term: **X** | Very short term: **X**
	International education and training supports knowledge development and management throughout disposal projects extending over several decades.
	When should this mechanism be implemented? This may or may not be equal to the target timescale.
	Pre-operational: **X** | Operational: **X** | Pre-closure: **X** | Post-closure:
	International education and training on RWM, as described here, should continue until closure of the repository.
	When should this mechanism be developed? This may or may not be equal to the implementation timescale.
	Done: **X** | Pre-operational: | Operational: | Pre-closure: | Post-closure:
	International education and training on RWM, as mechanisms and concepts, readily exist. Their fine-tuning according to the topical matters of the time can be considered part of their implementation.
Characteristics	Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?
	Intentional: **X** | Unintentional: | Cannot be controlled:
	International education and training programmes would be developed and implemented intentionally.
	Is the mechanism mainly tangible or intangible?
	Tangible: | Intangible: **X**
	Education and training are in themselves intangible, but supported by tangible devices such as textbooks and equipment (e.g. radioactivity detectors).
	Does the mechanism mainly rely on mediated transmission or non-mediated transmission?
	Mediated transmission: **X** | Non-mediated transmission:
	Education and training are prime examples of mediated transmission as they are about the transfer of information and knowledge from one generation to the next.
Actors	International education and training programmes are typically developed and organised by international agencies, organisations cooperating at the international level or upon the initiative of national states or organisations. The content is often defined by these agencies in collaboration with several stakeholders (such as universities, implementing agencies, industry, regulators, technical support organisations and research institutes, local community representatives). Multidisciplinarity is a key factor.
Main strengths/benefits	International education and training programmes are directly aimed at knowledge capacity building and preservation. Furthermore, they may foster the implementation of international standards, in particular regarding safety. E.g. many of the IAEA programmes are designed for safety education, to ensure that member countries commit an appropriate level of dedication and funding to nuclear safety and control. Similar effects can be pursued for the field of RK&M preservation.
Specific issues/challenges	Sustained interest and funding over time, especially in the context of nuclear phase-out, poses a significant challenge for this mechanism.
International dimension	The international nature is inherent to this element.
Connection to other approaches/ mechanisms	Culture, Education and Art: Research, education and training *(at the national, regional and local level)* International Mechanisms: International Standards and Guidelines: *(international education and training programmes help disseminating and implementing international standards and guidelines [e.g. IAEA Safety principles])* *RK&M preservation in general and all its approaches and mechanisms can be part of international education and training programmes*

Mechanism	International Education and Training Programmes
Information resources issued by the RK&M initiative	—
Other information resources	—
Examples	• NEA Nuclear Education, Skills and Technology (NEST) Framework: aims at addressing important gaps in nuclear skills capacity building, knowledge transfer and technical innovation in an international context. See www.oecd-nea.org/science/nest/ • IAEA Education & Training, see www-ns.iaea.org/training/ • European Nuclear Education Network (ENEN): dedicated to the preservation and the further development of expertise in the nuclear fields by higher Education and Training through the co-operation between universities, research organisations, regulatory bodies, the industry and any other organisations involved in the application of nuclear science and ionising radiation. See www.enen.eu/en/emsne/information.html • ANNETTE Project (Advanced Networking for Nuclear Education, Training and Transfer of Expertise), see www.enen.eu/en/projects/annette.html • ELINDER: European Learning Initiatives for Nuclear Decommissioning and Environmental Remediation, see https://ec.europa.eu/jrc/en/training-programme/elinder

International archiving initiatives

Mechanism	International Archiving Initiatives				
Approach	International mechanisms				
Definition/description	Information resources set up and run by international agencies or privately-run and/or commercial initiatives, aimed at the permanent preservation of selected record collections of universal value and/or international scope. The preservation of "original" material (i.e. in its original format, on the original medium) is particularly important. Special care is taken to maintaining the context of each collection. There is, at present, no international archive dedicated to RWM. The IAEA does preserve the official records documenting its programme activities and its historical material on nuclear topics, including RWM. Similarly, records documenting the work of Euratom are part of the historical archives of the European Union.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	An international archiving initiative has the same general purpose as a national or local archive, i.e. selecting, acquiring, preserving and making available records (including both documents and objects) in a coherent and contextually meaningful manner. The difference lies in the scope of the archive, the responsible actors, and the content. Depending on their scope, existing initiatives – e.g. in the broader field of nuclear energy – already host selected records related to radioactive waste disposal. Under the aegis of an international organisation such as the IAEA, or independently, an international archiving initiative could be established to preserve material specifically dedicated to RWM, in particular records related to waste repositories. More generally, international (as compared to national) archives could also be dedicated to – and hence point to – the universal aspects of RK&M preservation, such as "legacy of past activities", "waste management" in general or "hazardous waste sites" in particular. Such initiatives can also point to national/regional/local archives.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records: **X**	Knowledge:	Memory:	Awareness:
	Archives preserve records with information. By paying special attention to maintaining contextual information and coherence among record collections, archives aim to support both users' ability to understand, interpret and use the content of the records (knowledge) and a broader awareness of events, people, places and levels of knowledge in the past (memory). If a dedicated international RWM archive would be established, its sheer existence would also support awareness.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail:		High level of detail: **X**		
	The focus of (whole) archives is on detailed information supporting knowledge, more than on basic information supporting awareness.				
	What is the main geographical or administrative-political scope (development/ implementation/operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field "International dimension" further below.]				
	Local:	Regional:	National:	International: **X**	Virtual: **X**
	Depending on the kind of international archive and its access policy, the geographical/administrative scope may be of limited relevance and its main functioning is online/virtual.				

<table>
<tr><th>Mechanism</th><th>International Archiving Initiatives</th></tr>
<tr><td rowspan="12">Timescales</td><td colspan="4">Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term: X</td><td>Medium term: X</td><td>Short term:</td><td>Very short term:</td></tr>
<tr><td colspan="4">While archives are always “used in the present”, their main aim is to preserve selected records for the longer timescales, rather than the very short and short term. If oversight of a particular repository were to be lost in the long term, international archives could help to re-establish it, based on the preserved records.</td></tr>
<tr><td colspan="4">When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational:</td><td>Operational:</td><td>Pre-closure: X</td><td>Post-closure: X</td></tr>
<tr><td colspan="4">For this mechanism, the implementation timescale refers to the transfer of records to international archives. Because of their focus on collections of records, the transfer is unlikely to happen throughout the operational phase.</td></tr>
<tr><td colspan="4">When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done:</td><td>Pre-operational:</td><td>Operational: X</td><td>Pre-closure: X</td><td>Post-closure: X</td></tr>
<tr><td colspan="4">For this mechanism, the development timescale refers to the creation of a dedicated international archive, or to collaboration with existing international initiatives to transfer radioactive waste disposal related records.</td></tr>
<tr><td rowspan="8">Characteristics</td><td colspan="4">Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td>Intentional: X</td><td>Unintentional:</td><td>Cannot be controlled:</td></tr>
<tr><td colspan="4">International archiving initiatives are intentional.</td></tr>
<tr><td colspan="4">Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td>Tangible: X</td><td>Intangible:</td></tr>
<tr><td colspan="4">Archives and their content are tangible.</td></tr>
<tr><td colspan="4">Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td>Mediated transmission: X</td><td>Non-mediated transmission: X</td></tr>
<tr><td colspan="4">Archives use both mediated and non-mediated transmission. While the collection of records is continuously and actively maintained for preservation and accessibility purposes (mediated transmission), the content of the individual records is fixed and is transferred in a non-mediated way.</td></tr>
<tr><td>Actors</td><td colspan="4">An international archiving initiative dedicated to RWM may be set up and run by an international agency or a private organisation. Collaboration between implementing agencies, regulators, states and organisations such as national archives will be required in the decision and development of such an initiative.
These actors would also be involved in the decision to make use of an appropriate existing archive initiative outside the field of RWM.
Archiving specialists should be involved.
The broader the societal awareness of the existence of the archive and the potential to make use of it, the better.</td></tr>
<tr><td>Main strengths/benefits</td><td colspan="4">The main mission of any archive is the long-term preservation of collections of records in order to ensure access over an indefinite period of time. Access relates to both “form” (integrity of the information carrier) and “content” (understandability through providing coherence and context).
Keeping in mind the timescales of RWM, initiatives with an international scope and organisation add to diversity and redundancy, since national borders and actors may change. The international level adds to the spread of information related to radioactive waste. International initiatives can form a centre that points to national/regional/local archives.</td></tr>
<tr><td>Specific issues/challenges</td><td colspan="4">International archiving initiatives are more challenging to set up than national/ regional/local archives. If developed as a co-operation project between several countries, their success will depend on the willingness to find a shared vision and modus operandi, and their longevity on the future development of international relations.
The effectiveness of financial support depends on the willingness or the capacity of individual states to provide specific funds to the international organisation. Therefore, solid support – of the need for RK&M preservation in general and of the international archive in particular – from the organisations of the participating states seems to be a pre-requisite for reasonable longevity of an international archive.
Relationships with national and regional archives must also be considered, as there may be legal requirements to deliver certain records to these bodies.
For digital international archives, issues regarding technological compliance and maintenance, as well as the management of access rights, must be considered. For physical archives, accessibility may be challenging in light of the physical distance, especially for individual actors.</td></tr>
<tr><td>International dimension</td><td colspan="4">The international nature is inherent to this mechanism.</td></tr>
</table>

Mechanism	International Archiving Initiatives
Connection to other approaches/ mechanisms	Memory Institutions: Archives Time Capsules: *Mediated time capsules containing records of international relevance can be considered as a specific kind of international archive.* Regulatory Framework: Safeguards *(as part of its archive, the IAEA preserves records on past activities, including the application of safeguards provisions)* Dedicated record sets and summary files: KIF; SER *(copies could be preserved in a dedicated international archive)*
Information resources issued by the RK&M initiative	—
Other information resources	—
Examples	• IAEA Archive: www.iaea.org/resources/archives • Historical Archives of the European Union: www.eui.eu/Research/HistoricalArchivesOfEU • Archives of CORDIS, Community Research and Development Information Service of the European Commission (documents the results of European projects): https://cordis.europa.eu/guidance/archive_en.html • Svalbard Global Seed Vault www.regjeringen.no/en/topics/food-fisheries-and-agriculture/svalbard-global-seed-vault/id462220

Regulatory framework

National regulatory framework

Mechanism	National Regulatory framework				
Approach	Regulatory Framework				
Definition/description	This mechanism is about national laws, regulations and regulatory guidelines (hereafter referred to as "regulation") – including compliance mechanisms – regarding the preservation of RK&M for radioactive waste repositories.				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	A lack of dedicated regulation and its enforcement has been identified as a key cause of RK&M loss (OECD, 2014). A national regulatory framework should equip actors nationally involved with RWM with requirements, guidelines and responsibilities that are clear enough to develop and implement systemic RK&M preservation strategies. A national regulatory framework can at minimum include guidelines related to information preservation, e.g. archiving records. The preservation of knowledge and memory are more difficult to regulate directly, but are just as important. Therefore, a national regulatory framework should also include consideration of the preparation and implementation of RK&M preservation mechanisms complementary to archives, such as developing a key information file (KIF), public information dissemination activities, land use control, monitoring, markers, etc. A national regulatory framework should be in line with international regulations, but adapted to the national context, regarding both the content of the regulation (the various mechanisms) and the (participatory) procedures to implement it. It should go beyond short-term, operational requirements alone and proactively focus on the period after closure. While developing this mechanism and controlling its efficacy is a key responsibility of national nuclear regulators, other regulatory fields, actors and levels (e.g. environmental protection, spatial planning, safety, security, heritage preservation and archiving; local, regional, international) are also involved.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory or awareness?				
	Information: **X**	Records: **X**	Knowledge: **X**	Memory: **X**	Awareness: **X**
	Different regulatory RK&M preservation mechanisms can address different levels of detail, different time frames, and involve different actors. Overall, a national regulatory framework should indirectly support the preservation of information, records, knowledge, memory and awareness.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail:		High level of detail: **X**		
	The national regulatory framework should be developed so as to promote the highest level of detail of RK&M preservation. This does not mean that mechanism with lower levels of detail should be excluded.				
	What is the main geographical or administrative-political scope (development / implementation / operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation?				
	Local:	Regional:	National: **X**	International:	Virtual:
	The national regulatory framework should comply with international regulations. As for all national regulation, accordance should be sought with the local and regional level, having regard to the subsidiarity principle.				

<table>
<tr><th>Mechanism</th><th>National Regulatory framework</th></tr>
<tr><td rowspan="13">Timescales</td><td>Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term: | Medium term: X | Short term: X | Very short term:</td></tr>
<tr><td>A functional regulatory framework for RK&M preservation demands compliance mechanisms, which implies the existence of institutional control mechanisms. The timescale thus depends on how long institutional control can be performed effectively and how long a future society deems it useful to have particular regulations in place. Generally speaking, a regulatory framework may be expected to be in place for as long as oversight lasts, i.e. throughout the short and medium term, and should aim to avoid or defer the arrival of the long term (i.e. the loss of oversight).</td></tr>
<tr><td>When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational: X | Operational: X | Pre-closure: X | Post-closure: X</td></tr>
<tr><td>A national regulatory framework addressing RK&M issues should be implemented before the operational phase and should continue to be implemented across all phases, for as long as society deems it useful.</td></tr>
<tr><td>When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: | Pre-operational: X | Operational: X | Pre-closure: X | Post-closure:</td></tr>
<tr><td>Regulations will probably be developed, revised and updated throughout the repository lifetime, almost certainly until the facility is closed and possibly after closure.</td></tr>
<tr><td rowspan="9">Characteristics</td><td>Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td>Intentional: X | Unintentional: | Cannot be controlled:</td></tr>
<tr><td>The national regulatory framework is developed and implemented intentionally.</td></tr>
<tr><td>Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td>Tangible: X | Intangible: X</td></tr>
<tr><td>A regulatory framework involves both tangible (e.g. the recorded regulations itself, the regulatory required records) and intangible elements (e.g. the control of the compliance with the regulatory framework, the training of regulatory staff).</td></tr>
<tr><td>Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td>Mediated transmission: X | Non-mediated transmission:</td></tr>
<tr><td>Regulation needs to remain administratively and societally anchored and functional in order to be effective. Regulatory frameworks are under continuous development and need to be transferred from one generation to the next. Regulation is an ongoing process.</td></tr>
<tr><td>Actors</td><td>The main actor regarding the development of national laws, regulations and guidance is the regulator, although other government agencies and stakeholders can be involved. International organisations can be the primary actor for the development of international directives, guidelines, standards etc. which, depending on their regulatory force, may or may not be implemented by the individual nations. Apart from the nuclear regulator, regulatory agencies involved in the fields of environmental protection, spatial planning, safety, security, heritage preservation and archiving may also be relevant actors for the development of and compliance with this mechanism.</td></tr>
<tr><td>Main strengths/benefits</td><td>A regulatory framework with clear regulatory guidance and enforcement is a base condition for effectively carrying out RK&M preservation. It supports the availability of accurate and reliable information, as well as accountability.
Regulation related to RK&M preservation in other fields can be positive for RK&M preservation from a systemic point of view, by providing opportunities for collaboration, learning and redundancy.</td></tr>
<tr><td>Specific issues/challenges</td><td>Current regulatory frameworks related to preservation of RK&M for radioactive waste repositories focus on short-term, operational requirements, notably in the context of licensing.
A variety of RK&M preservation related regulation exists in other fields, which may be positive (see above), but which may also cause divergence and lack of clarity on the level of both content and responsibilities. The national regulatory framework needs to identify and thus plan ahead clear and transparent responsibilities for RK&M preservation, including a possible change in, and/or transfer of, responsibilities after the end of the operational phase.
RK&M preservation is a dynamic, context-dependent issue that does not easily lend itself to being translated into tight rules. The success of a regulatory framework can only be judged in an ongoing manner, by assessing whether it establishes the relevance and responsibility in the minds and attitudes of waste producers, regulators, implementing agencies, other stakeholders and the general public today, and whether that need and responsibility is understood and passed on to the next generation. Minds and attitudes are difficult to regulate. Hence regulation should focus not only on formulating guidelines and actions that are as specific as possible, but also on mechanisms to control their efficacy, today and in the future.</td></tr>
</table>

Mechanism	National Regulatory framework
International dimension	International organisations can be the primary actor for the development of international directives, guidelines, standards etc. which, depending on their regulatory force, may or may not be implemented by the individual nations. Ideally, international guidelines and standards would provide some global framework for the uptake of long-term RK&M preservation in RWM regulation. International guidelines and standards might be beneficial in order to have compatible national approaches in RK&M preservation matters, at least on a generic level. International organisations can also be involved with for instance peer review of national regulatory frameworks.
Connection to other approaches/ mechanisms	Regulatory Framework: Safeguards International Mechanisms: International regulations and agreements; International standards and guidelines Oversight Provisions: Clear and planned responsibilities *This mechanism is connected to all approaches and mechanisms of a nationally chosen RK&M preservation strategy which will be legally laid down.*
Information resources issued by the RK&M initiative	• NEA (2014), Preservation of Records, Knowledge and Memory across Generations. Loss of information, records, knowledge and memory in the area of conventional waste disposal NEA/RWM/R(2014)3. • NEA (2018), Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Catalogue of legislation, regulation and guidance governing the preservation of RK&M for radioactive waste repositories, OECD, Paris.
Other information resources	—
Examples	See: NEA (2018), Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Catalogue of legislation, regulation and guidance governing the preservation of RK&M for radioactive waste repositories, OECD, Paris.

Safeguards

Mechanism	Safeguards				
Approach	Regulatory Framework				
Definition/description	The international treaty on the non-proliferation of nuclear weapons (NPT) and the European Euratom treaty are set up (among other purposes) to prevent the diversion of nuclear technology and materials for the purpose of creating nuclear weapons. Safeguards are the institutional controls to verify compliance with (this part of) these treaties. In the context of disposal of radioactive waste, safeguard measures refer to having clear information about the fissile material content of the repository, verifying this information over time, and surveillance/monitoring of disposal sites, with the aim of making sure that no malevolent use of the technology/material occurs. Safeguards thus only apply to repositories that contain fissile material. For such repositories, current IAEA guidance states that safeguards will also continue after repository closure, with activities focusing on assuring that no intrusions occur that might remove fissile material from the repository (IAEA, 2010).				
How does this mechanism contribute to RK&M preservation/ How can it be implemented?	The IAEA emphasise the importance of adequate nuclear material accountancy and advocates measures to ensure a continuity of knowledge relating to the nuclear material inventories. Safeguards thus include activities that overlap with RK&M preservation, such as record keeping, record verification over time, and knowledge transfer. Safeguards take place within an international, institutional setting with a dedicated regulatory framework. Repository safeguards related RK&M is in the hands of and requires collaboration between the state, the implementing agency and the dedicated international organisations.				
Scope	Does the mechanism mainly preserve information, records, knowledge, memory, or awareness?				
	Information: **X**	Records: **X**	Knowledge: **X**	Memory:	Awareness:
	The objective of safeguards is to confirm the whereabouts of fissile material. For the case of repositories containing fissile material, this implies the preservation of information, records and knowledge about the location and design of the repository and its fissile material content. Safeguards also imply the preservation of more general information, knowledge and memory related to the nuclear field, both techno-scientifically and socio-politically.				
	What is the level of detail addressed/provided by the mechanism?				
	Low level of detail:			High level of detail: **X**	
	Safeguards address and provide detailed information about the fissile material content of repositories. The level of detail of information related to the repository itself and its functioning is likely to be less detailed in this context.				

<table>
<tr><th>Mechanism</th><th>Safeguards</th></tr>
<tr><td rowspan="3">Scope</td><td>What is the main geographical or administrative-political scope (development/implementation/ operation) of the mechanism? On which scale does the mechanism notably enable RK&M preservation? [Note also the field “International dimension” further below.]</td></tr>
<tr><td>Local: | Regional: | National: X | International: X | Virtual:</td></tr>
<tr><td>Safeguards are a national commitment under international inspection.</td></tr>
<tr><td rowspan="10">Timescales</td><td>Which timescale(s) is this mechanism mainly aimed at (target timescale)?</td></tr>
<tr><td>Long term: | Medium term: X | Short term: X | Very short term:</td></tr>
<tr><td>There is no specific time limit concerning how long safeguards measures should continue. Previous IAEA guidance states that the termination of safeguards will be determined based on when the nuclear material subject to safeguards has been consumed, diluted, or has become practicably irrecoverable (IAEA, 1972). The current IAEA guidance related to geological disposal states that safeguards will continue after repository closure. The safeguards principles applied during the operational phase would continue after closure for as long as the repository remains under safeguards, i.e. for as long as the NPT is in force (IAEA, 2010).
Overall, the longevity of safeguards depends on the willingness and ability of a future society to continue safeguard activities. Safeguards are likely to continue throughout the period of oversight, i.e. in the short and medium term, and its RK&M preservation function can thus be seen as targeting these timescales.</td></tr>
<tr><td>When should this mechanism be implemented? This may or may not be equal to the target timescale.</td></tr>
<tr><td>Pre-operational: X | Operational: X | Pre-closure: X | Post-closure: X</td></tr>
<tr><td>The creation of the relevant records and knowledge should take place in the pre-operational and operational phase, for the detailed records on fissile material (before the waste is on site) and on the whereabouts of it (parallel to operations) respectively. According to the current guidelines, records and knowledge should be preserved and their validity checked for as long as the nuclear material in the geological repository remains under safeguards.</td></tr>
<tr><td>When should this mechanism be developed? This may or may not be equal to the implementation timescale.</td></tr>
<tr><td>Done: | Pre-operational: X | Operational: | Pre-closure: | Post-closure:</td></tr>
<tr><td>Articles 3 and 6 in the European regulation (Euratom No 302/2005) state that the Commission shall adopt particular safeguards provisions for a repository when a basic technical description of the facility is presented. The IAEA (2010) similarly states that during the pre-operational phase specific safeguards measures will be developed based on the site characteristics and repository design.</td></tr>
<tr><td rowspan="8">Characteristics</td><td>Should the mechanism be implemented intentionally (e.g. time capsules) or is its emergence largely unintentional (e.g. surface traces) or can it not be fully controlled (e.g. art work)?</td></tr>
<tr><td>Intentional: X | Unintentional: | Cannot be controlled:</td></tr>
<tr><td>Safeguards are an intentional mechanism.</td></tr>
<tr><td>Is the mechanism mainly tangible or intangible?</td></tr>
<tr><td>Tangible: X | Intangible: X</td></tr>
<tr><td>Some elements of safeguards are tangible (e.g. records, fences, the treaty as a record), some are intangible (e.g. the treaty as an agreement, the knowledge of how to carry out inspections).</td></tr>
<tr><td>Does the mechanism mainly rely on mediated transmission or non-mediated transmission?</td></tr>
<tr><td>Mediated transmission: X | Non-mediated transmission:</td></tr>
<tr><td>Safeguards entail ongoing activities related to the verification of information about the fissile material inventory, which in turn requires the transfer of records, knowledge and memory about these materials.</td></tr>
<tr><td>Actors</td><td>Safeguards are issued and controlled on a national (state) as well as an international (IAEA and Euratom) level. International regulations require states to decide the particular safeguard provisions for a final repository, in close consultation with the implementing agency and the regulator (Euratom No 302/2005).</td></tr>
<tr><td>Main strengths/benefits</td><td>For as long as safeguards are in place, safeguards relevant information, records, knowledge and memory will be produced and preserved. These will relate to repository locations, designs and (part of) their content, as well as to more general techno-scientific and socio-political information, knowledge and memory related to the nuclear field.
Safeguards take place within an international, institutional control setting with a dedicated regulatory framework, which is promoted as an element of robustness in an RK&M strategy. For a number of European countries, the fact that there are two international mechanisms (IAEA and Euratom) also adds to redundancy.
Safeguards are likely to include efforts that overlap with RK&M preservation, such as record keeping, record verification, knowledge transfer and monitoring. Both will benefit from developing preservation techniques and methods for handling large quantities of documentation over long time spans.</td></tr>
</table>

Mechanism	Safeguards
Specific issues/ challenges	Whereas the general aim of RK&M preservation is to keep awareness of disposal sites and to enable future generations to make informed decisions, the general aim of safeguards, from a security and malevolent use of nuclear material point of view, can be said to be the opposite. Tensions may thus arise between the classified and expertocratic nature of safeguards on the one hand, and the open, participatory nature of RK&M preservation on the other. The current regulation on safeguards includes all kinds of facilities that handle nuclear material, but for geological repositories considerations are still at a conceptual level. Discussions are ongoing within the IAEA and the European Commission on how international safeguards should be implemented in such facilities, considering both the operational and the post-closure phase and the desired continuity between those phases (including issues such as institutional continuity, handling of classified documents, economic provisions, etc.). Safeguards only apply to disposal facilities containing fissile material, and will thus not support to RK&M preservation for other repositories.
International dimension	International organisations (Euratom and IAEA) are central to the development and conduct of safeguards provisions.
Connection to other approaches/ mechanisms	International mechanisms: international regulations and agreements; international inventories and catalogues; international co-operation; international education and training programmes; international archives Regulatory framework: national regulatory framework Oversight provisions: monitoring; clear and planned responsibilities; land use control Knowledge management: knowledge risk analysis Memory institutions: archives Dedicated record sets and summary files: SER
Information resources issued by the RK&M initiative	• Ormai, P. (2011). *The Connection between the Areas of Safeguards and Physical Protection and Record and Memory Keeping*. In: NEA (2012). The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue. Workshop proceedings. 11-13 October 2011, Issy-les-Moulineaux, France. Item 26. • NEA (2013). The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding. Proceedings of the second RK&M Workshop. 12-13 September 2012, Issy-les-Moulineaux, France. Items 9 & 10, OECD, Paris.
Other information resources	• European Commission (2005). Commission Regulation (Euratom) No 302/2005 of 8 February 2005 on the application of Euratom safeguards - Council/Commission statement. • IAEA (1972). The structure and content of agreements between the Agency and States required in connection with the treaty on the non-proliferation of nuclear weapons. INFCIRC/153. IAEA, Vienna. • IAEA (1996). Issues in Radioactive Waste Disposal. IAEA-Tecdoc-909. IAEA, Vienna. • IAEA (2010). Technological Implications of International Safeguards for Geological Disposal of Spent Fuel and Radioactive Waste. NW-T-1.21. IAEA, Vienna. • IAEA (2011). Model Integrated Safeguards Approach for a Geological Repository. IAEA Department of Safeguards (SGCP-CCA) SG-PR-1306. IAEA, Vienna. • IAEA (2017). Technologies Potentially Useful for Safeguarding Geological Repositories. ASTOR Group Report 2011-2016. STR-384. IAEA, Vienna. • NEA (1995). Future human actions at disposal sites: a report from the NEA Working Group on Assessment of Future Human Actions at Radioactive Waste Disposal Sites. OECD, Paris.
Examples	• Safeguards and verification | IAEA, see www.iaea.org/topics/safeguards-and-verification • Safeguards to avoid misuse - European Commission, see https://ec.europa.eu/energy/en/topics/nuclear-energy/safeguards-avoid-misuse • For a national example, see www.onr.org.uk/safeguards/index.htm

2.3. **Mechanisms overview table**

This annex provides an overview table of the way the different RK&M preservation mechanisms vary with regard to their key characteristics, based on the filled out tick boxes of the mechanism description sheets (Annex 2.2). It aids to visualise diversity among the key characteristics, which is fundamental to the idea of a systemic strategy.

This table can also be used as a practical tool to compare and combine approaches and mechanisms in such a way that, in order to achieve robustness, different mechanisms of a variety of approaches are selected (rows) that cover a variety of key characteristics (columns). The table can be downloaded in Excel format from the RK&M initiative website at www.oecd-nea.org/rwm/rkm.

The limitations of the overview table are the following. The table only includes mechanism description components that were elaborated by using tick boxes in the mechanism description sheets (Annex 2.2). Establishing diversity with regard to involved actors and comparing main strengths/benefits and issues/challenges is thus a task for which the table does not offer visual assistance. The table also does not display the inter-connectedness among the mechanisms, which is the second fundamental of a systemic strategy.

Approaches	Mechanisms	Scope												Characteristics							Timescales										
		RK&M Type					Level of Detail		Geographical Scope					Intentionality			Tangi-bility		Trans-mission Modes		Target Timescale				Implementation Timescale				Development Timescale				
		Information	Records	Knowledge	Memory	Awareness	Low Level of Detail	High Level of Detail	Local	Regional	National	International	Virtual	Intentional	Unintentional	Cannot be Controlled	Tangible	Intangible	Mediated	Non-Mediated	Very Short Term	Short Term	Medium Term	Long Term	Pre-Operational	Operational	Pre-Closure	Post-Closure	Done	Pre-Operational	Operational	Pre-Closure	Post-Closure
Dedicated Record Sets and Summary Files	Key Information File (KIF)	x	x		x		x		x	x	x	x		x			x		x	x		x	x			x	x	x	x	x	x	x		
	Set of Essential Records (SER)	x	x					x	x	x	x			x			x		x	x			x		x	x	x	x	x	x	x		
Memory Institutions	Archives	x	x				x		x	x	x		x	x			x		x	x			x	x	x	x			x		x	x	
	Librairies	x		x	x		x	x	x	x	x		x	x	x	x	x		x		x	x	x						x				
	Museums	x			x	x	x		x	x	x	x	x	x	x	x	x		x			x	x						x				
Markers	Surface Markers	x				x	x		x					x			x			x			x	x			x	x	x	x	x	x	
	Monuments	x			x	x	x		x					x			x			x			x	x			x	x		x	x	x	
	Sub-Surface Markers					x	x		x					x			x			x				x			x	x			x	x	
	Deep Geological Markers					x	x		x					x			x			x				x		x	x			x	x		
	Surface Traces					x	x		x	x				x	x	x	x			x				x			x	x		x	x	x	
Time Capsules	Large Visible Time Caspules	x	x			x		x	x	x	x			x			x			x				x			x	x	x		x	x	
	Large Invisible Time Capsules	x	x					x	x	x	x			x			x			x				x			x	x			x	x	
	Small Time Capsules	x	x					x	x					x			x			x				x		x	x	x		x	x	x	
Culture, Education and Art	Industrial Heritage				x	x	x		x	x				x		x	x		x	x				x			x	x	x			x	x
	Alternative Reuse of the Disposal Site/Infrastructure				x		x		x	x				x			x		x					x				x		x		x	
	Heritage Inventories and Catalogues	x				x	x			x	x	x	x	x			x		x					x		x	x	x					
	Local History Societies	x	x		x		x		x	x				x		x	x	x	x			x	x		x	x	x		x		x	x	
	Intangible Cultural Heritage				x	x	x		x	x				x	x	x		x	x				x			x	x	x			x	x	x
	Education, Research and Training	x		x			x	x		x	x			x				x	x		x	x	x		x	x	x	x	x				
	Public Information Dissemination Activities			x			x		x	x	x			x			x	x	x		x	x			x	x			x				
	Art				x	x	x			x	x	x	x	x		x	x	x	x			x	x			x	x		x	x	x		
Knowledge Management	Knowledge Retention Tools			x				x	x				x	x			x	x	x		x	x			x	x	x	x	x	x	x		
	Knowledge Risk Analysis			x				x	x				x	x			x	x	x		x	x			x	x	x		x	x	x		
	Knowledge Sharing Philosophy			x				x	x				x	x			x	x	x		x	x			x	x	x		x	x	x		
Oversight Provisions	Monitoring		x	x	x			x	x					x			x		x			x	x		x	x	x	x		x	x		
	Land Use Control	x			x	x	x		x					x			x	x	x				x					x		x	x		
	Clear and Planned Responisibilities	x	x	x	x			x	x	x	x			x				x	x			x	x		x	x	x	x	x	x	x		
International Mechanisms	International Regulations and Agreements	x	x			x	x	x				x		x			x	x	x			x	x		x	x	x	x	x		x		
	International Standards and Guidelines	x	x	x			x	x				x		x			x	x	x		x	x	x		x	x	x	x	x		x		
	International Inventories and Catalogues	x				x	x	x				x	x	x			x		x			x	x		x	x			x	x	x		
	International Cooperation	x		x				x				x		x				x	x		x	x	x		x	x	x	x	x	x	x		
	International Education and Training Programmes			x				x				x		x				x	x		x	x			x	x	x		x				
	International Archiving Initiatives	x	x					x				x	x	x			x		x	x			x	x			x	x			x	x	x
Regulatory Framework	National Regulatory Framework	x	x	x	x	x		x			x			x			x	x	x			x	x		x	x	x	x		x	x		
	Safeguards	x	x	x				x			x	x		x			x	x	x			x	x		x	x	x	x		x			

Annex 3. **Deliverables of the RK&M initiative**

Workshop and conference proceedings

NEA (2015), *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate,* OECD, Paris, www.oecd-nea.org/rwm/pubs/2015/7259-constructing-memory-2015.pdf.

NEA (2013), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Improving Our Understanding", www.oecd-nea.org/rwm/reports/2013/rwm-r2013-3.pdf.

NEA (2012), "The Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Scoping the Issue: Workshop proceedings", www.oecd-nea.org/rwm/docs/2012/rwm_r_2012_6.pdf.

Studies

NEA (2015), "International Mechanisms to Support Records, Knowledge and Memory Preservation Over the Short and Medium Term", NEA/RWM/R(2015)2, www.oecd-nea.org/rwm/docs/2015/rwm-r2015-2.pdf.

NEA (2014a), "Markers – Reflections on Intergenerational Warnings in the Form of Japanese Tsunami Stones", NEA/RWM/R(2014)4, www.oecd-nea.org/rwm/docs/2014/rwm-r2014-4.pdf.

NEA (2014b), "Preservation of Records, Knowledge and Memory across Generations (RK&M). Monitoring of Geological Disposal Facilities – Technical and Societal Aspects", NEA/RWM/R(2014)2, www.oecd-nea.org/rwm/docs/2014/rwm-r2014-2.pdf.

NEA (2014c), "Preservation of Records, Knowledge and Memory across Generations: Loss of Information, Records, Knowledge and Memory in the Area of Conventional Waste Disposal", NEA/RWM/R(2014)3, www.oecd-nea.org/rwm/docs/2014/rwm-r2014-3.pdf.

NEA (2013), "A Literature Survey on Markers and Memory Preservation for Deep Geological Repositories", www.oecd-nea.org/rwm/docs/2013/rwm-r2013-5.pdf.

Reports

NEA (this report), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Final Report of the RK&M Initiative*, OECD, Paris.

NEA (2019), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Developing a Key Information File for a Radioactive Waste Repository*, OECD, Paris.

NEA (2018), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Reference Bibliography*, OECD, Paris.

NEA (forthcoming-a), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Catalogue of Legislation, Regulation and Guidance Governing the Preservation of RK&M for Radioactive Waste Repositories*, OECD, Paris.

NEA (forthcoming-b), *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Compiling a Set of Essential Records for a Radioactive Waste Repository*, OECD, Paris.

Website

www.oecd-nea.org/rwm/rkm

Annex 4. **Members and participating organisations of the RK&M initiative**

The members of the RK&M initiative (left column) are the contact persons of the participating organisations (right column). This list reflects the membership in Phase II of the RK&M initiative, from April 2014 to April 2018. The members contributed in various degrees to the deliverables of the project.

Arne Berckmans Jean-Paul Boyazis	ONDRAF/NIRAS, Belgium
Jantine Schröder	SCK•CEN, Belgium
Mihaela Ion	NWMO, Canada
Simone Brander	BFE/SFOE, Switzerland
Anne Claudel	NAGRA, Switzerland
Martin Eliáš Miroslav Kučerka Ilona Pospíšková	SÚRAO/RAWRA, Czech Republic
Karsten Leopold	BfE (until 2017 BfS), Germany
Jens Wolf Ulrich Noseck	GRS-BS, Germany
Stephan Hotzel	GRS-K, Germany
Joaquín Farias-seifert	Enresa, Spain
Kai Hamalainen	STUK, Finland
Patrick Charton Gwenaëlle Clerc Catherine Cobat-Vittecoq Jean-Noël Dumont Vincent Maugis	Andra, France
József I. Fekete	PURAM/RHK, Hungary
Hisakazu Nakata	JAEA, Japan
Jiro Eto	RWMC, Japan
Pavel Malinovskii Tatyana Rakitskaya	ROSATOM, Russia
Håkan Lövblad Jonas Palm	Riksarkivet, Sweden
Erik Setzman Sofie Tunbrant Georg Lindgren Carl-Henrik Pettersson	SKB, Sweden
Simon Wisbey	NDA-RWM, United Kingdom
Abe Van Luik Russ Patterson	DOE, United States
Thomas M. Klein	Contractor to the DOE, United States
Philippe Van Marcke Peter Ormai	IAEA
Radu Botez Massimo Ciambrella Pierre-Henri De La Codre Marine Formentini Claudio Pescatore	NEA

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Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Final Report of the RK&M Initiative

Radioactive waste repositories are designed to isolate waste from the living environment without human intervention over extended periods of time. Nevertheless, the intention is not to abandon the repositories, but to provide the oversight that is necessary to ensure that they are not forgotten by society. In response to this challenge, the Nuclear Energy Agency launched the international initiative "Preservation of Records, Knowledge and Memory (RK&M) Across Generations". As a result, an in-depth understanding of this issue was developed, as well as a specific methodology to address it. The RK&M preservation toolbox, for example, offers a menu with 35 different preservation mechanisms and guidelines on how to combine and implement them.

This report may be used as a general guide to the RK&M preservation topic. It presents a historical review, addresses ethical considerations, analyses the fundamentals of RK&M preservation, outlines various mechanisms and indicates how to develop these mechanisms into a systemic RK&M preservation strategy. The report aims to inspire and assist a variety of actors so that they can discuss and develop national and repository-specific RK&M preservation strategies.

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