

Development of an Integrated System for the Long-term Preservation of Records, Knowledge and Memory relating to Radioactive Waste Disposal Facilities – 17099

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ABSTRACT

The Nuclear Energy Agency (NEA) has co-ordinated an international initiative to develop a common approach to the preservation of records, knowledge and long-term memory (RK&M), focused on radioactive waste disposals. The work programme has run in two phases, starting in 2011, with the current phase of the project due to be completed in 2018. Preparations for final reporting are now underway.

The detailed implementation of an approach to RK&M preservation for any disposal facility will always remain a national decision. However, the NEA project has produced a 'menu' of tools and techniques that can be accessed and adapted to suit national needs. The common source of these menu components will help to ensure that the memory of the repository is kept alive, that messages to future populations can be clearly understood, and that evidence derived from the disposal environment can be properly interpreted.

This paper describes the vision for implementation of the RK&M initiative within national programmes. Practical testing of some components of the menu of tools and techniques is currently underway in France, Sweden and USA, with encouraging results. Other disposal facilities, both under development or in planning, are invited to 'road test' the products and provide feedback. Refinement and maintenance of the tools remains important, and the NEA is committed to ensuring the continued accessibility and availability of the project outputs into the future.

INTRODUCTION

The international initiative to develop a common approach to the preservation of records, knowledge and long-term memory (RK&M), focused on radioactive waste disposals, is co-ordinated by the Nuclear Energy Agency (NEA) with a work programme supported by experts from 13 nations and 2 external bodies.

Progress with the RK&M initiative has been reported widely, including the innovative 'Constructing Memory' conference, held in France in 2014 [1]. Previous WM meetings have hosted a number of presentations and panel discussions on the subject. This paper sets out a summary of the main outputs from the project, which will be formally reported in due course.

GUIDING PRINCIPLES

The following guiding principles were established in the first phase of the project:

- maintaining RK&M for a radioactive waste repository after its closure will allow future members of society to make informed decisions regarding the repository and its contents, and will help to prevent inadvertent human intrusion
- enabling future members of society to make these informed decisions is part of a responsible, ethically-sound and sustainable radioactive waste management strategy
- preparing for RK&M preservation is best addressed while waste management plans are being designed and implemented
- systems for preserving RK&M will need to be flexible and adaptable over time
- 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 development of a coherent RK&M system is being undertaken to be consistent with the recommendations of the International Commission on Radiological Protection (ICRP), related to the geological disposal of long-lived, solid radioactive waste. In particular, the concept of oversight or 'watchful care', which is developed in ICRP-122, is identified as the crucial factor that influences the application of the protection system over the different phases in the lifetime of a disposal facility. Three main time frames are considered:

- time of direct oversight, when the disposal facility is being implemented and is under active supervision
- time of indirect oversight, when the disposal facility is sealed and oversight is being exercised by regulators or special administrative bodies or society at large to provide additional assurance on behalf of society
- time of no oversight, when oversight is no longer exercised in case memory of the disposal facility is lost.

These time-frames are illustrated in Figure 1, reproduced from ICRP-122 [2].

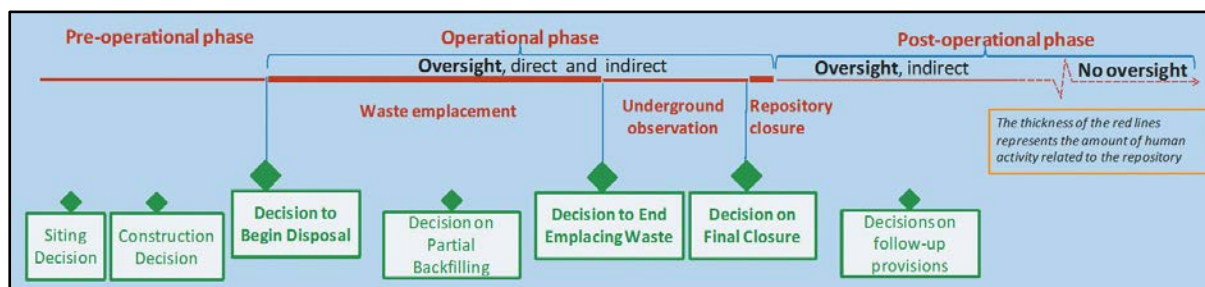


Fig. 1. The three time frames considered in the RK&M work.

VISION FOR RK&M SYSTEM

The overarching vision for the RK&M project is the development and publication of a 'menu' of tools and techniques to preserve information about geological disposal facilities. National disposal programmes can select components from

this menu to create a system that maximises the likelihood of information survivability, and meets the legal requirements in force.

This is referred to as the 'systemic approach', in which a variety of information avenues are established in order to maximize information understandability and survivability over the reference timescale. All of the mechanisms in a particular application would be chosen on the basis that they provide robustness through reinforcement, cross-referencing, and redundancy. The NEA project has set out proposals on how the systemic approach could be applied. Taking account of the identified threats and system evolution, it is proposed that disposal facilities should aim to build a lasting record, establish institutional oversight, and create incentives for retaining memory.

The menu contains a range of '*strategic components*', including: archives, cultural heritage, international mechanisms, markers, time capsules and oversight provisions. Each of the strategic components is composed from strategic elements, for which the RK&M project has developed unique descriptions, based on a standard template. The template covers the following areas:

- contribution to the RK&M approach
- responsibility for implementation
- main strengths and benefits
- specific issues and challenges
- links to other elements
- examples.

Taken together this descriptive material would allow an implementer to focus their attention on the most useful or contentious aspects of the developing system. The NEA RK&M project will also develop a strategic approach map, which sets out the relationship between the different strategic elements that make up the overall system.

The remainder of this paper describes the vision in more detail, starting with 'core information', then moving on to the concepts of information retention and transmission, and finally the strategic components, which form the building blocks of a full RK&M system.

CORE INFORMATION

The RK&M system is underpinned by the collation of core information, collectively considered to be fundamental to the RK&M concept. These include a glossary of key terms, a bibliography of published works, and a catalogue of international laws and regulations related to the preservation of RK&M. The first two of these are accessible through documents hosted on the NEA website [3].

The *glossary* of key terms has been kept as short as possible, extending only to about 30 definitions. This is to ensure that the overall RK&M approach is not overly specialised, and does not require application of a unique taxonomy. Most of these definitions are designed to clarify the use of the term in the context of their application.

The *bibliography* is a compendium of almost 200 publications, reports and books. It is constantly under review, with new material being added as it enters the public domain. It is designed to provide a first point of reference for any potential user of the RK&M system.

The *catalogue* of international laws and regulations relating to records and site markers covers each of the contributing nations, with additional material from the international bodies as appropriate. It is essentially a snapshot in time, and serves to demonstrate the regulatory and legal structures against which national approaches to RK&M preservation are being developed. There is no intention to imply that any of the legal structures are better, or more appropriate, than any other.

INFORMATION RETENTION AND TRANSMISSION

The RK&M project has explored the potential timescales for information retention and the likely survivability of 'messages'. The importance of learning from the past is noted, but it is recognised that the longest-lived human markings and structures can be difficult to interpret. The most promising methods for RK&M retention are considered to be formal archives and physical marker programmes, supported by the creation of incentives for local retention of memory. In addition it is considered that institutional bodies, particularly international initiatives, can form part of the solution. However, before describing methods of information transmission, it is important to note the ease with which information can be lost.

Information loss

Waste is a material that inherently has 'no value', so the prevailing human philosophy is that its disposal must be at the lowest possible cost. Traditional approaches to the handling of wastes are simply to dump them in an uncontrolled fashion, on the basis that the environment has an infinite capacity to absorb, degrade and disperse the wastes. Industrialisation has led to a massive increase in the scale and toxicity of the waste challenge, and the environmental movement has played a significant role in focusing attention on proper waste management and records.

History has shown that the challenges presented by technological wastes are only addressed properly when strong regulation and appropriate sanctions are in place. The RK&M project commissioned a study to identify the key factors with respect to the loss of knowledge over a period of little more than 100 years [4]. A key conclusion from this study is that information retention is highly dependent on continuity issues: particularly of institutions and funding. In the absence of societal discontinuities such as warfare, it is rare to lose all information about waste disposals, although details can be lost quickly. It is also clear that many records are made with insufficient data to inform remediation actions, and that once lost, records are very difficult to re-construct.

Information transmission

The RK&M project is developing a communication strategy based on simultaneous, redundant and independent pathways for information. This is termed a 'dual-track' approach, on the basis of mediated and non-mediated transmission into the future. The former relies on the 'relay' approach, explicitly passing on information from one generation to another, the latter relies on the survivability and longevity of messages, which would address the future directly.

In the case of *mediated transmission*, the record is passed on from one generation to another. Each generation may review the records and undertake the necessary steps to ensure the continuity of readability (legibility and language), and understandability (comprehension and context). *Non-mediated transmission* places no reliance on the presence of intermediaries and the record

is delivered directly (e.g. in its original format) from the present time to the future receiver.

It is recognised that the two tracks may address different target audiences and consider different levels of detail and different technical means to achieve survivability.

STRATEGIC COMPONENTS

As noted previously, the RK&M project has identified a menu of 'strategic components', which can be used to implement an information provision system for a national facility. Each of the strategic components is composed from strategic elements, for example the 'markers' component is made up from the following elements: surface traces, surface markers and monuments, and underground markers. A high level description is provided here for the following strategic components: archives, cultural heritage, international mechanisms, markers, time capsules and oversight provisions.

Archives

In the context of the RK&M project, archives are defined through their long-term preservation mission, to preserve collections of records for future generations, with no time limit. They are therefore a key institutional component of the RK&M preservation process, and this distinguishes them from libraries, which are usually created with the intention of providing public access to collections of published materials. Depending on their respective aims and scope, different types of archives (e.g. national, regional, cultural, nuclear), may play a different role in preserving and granting access to relevant records.

As records are produced by a waste management organisation, they are usually stored in an internal records management system. In many countries, legislation requires that records from specific institutions be ultimately transferred to the national archive for preservation. National archives, with their typically long experience in the continuous management and preservation of such records, for which they have established policies and standards, are a key component in the preservation process of RK&M over time.

Cultural heritage

Cultural heritage has been explored as a possible mechanism to foster memory, and a preliminary understanding of cultural heritage forms part of the mediated transmission component within a dual track strategy. It also features in the work of the Forum for Stakeholder Confidence group of the NEA, which has been proposing to build waste management facilities as part of the community [5].

Cultural heritage refers to the legacy of a group or society that is inherited from past generations, maintained in the present and bestowed for the benefit of future generations. It includes tangible heritage (such as buildings, monuments, man-made landscapes, books, works of art and artifacts), intangible culture (such as folklore, traditions, knowledge), and components from the natural world (such as culturally significant landscapes and geologies, and biodiversity). The concept of finding an incentive for the local society to retain the memory could be linked to cultural heritage through some of these attributes.

It is acknowledged that what may become 'cultural heritage' is not easily pre-defined or controlled. In particular, cultural heritage changes over time, and interpretations of preserved cultural heritage are subject to continuous

reinterpretation. Therefore cultural heritage does not assure continued understanding, as the ability to make sense of today's values and knowledge cannot be guaranteed. However, the combination of tangible and intangible components is proposed as a component within the overall systemic approach.

International mechanisms

As part of this systemic approach, the RK&M project has examined the potential role of international mechanisms in fostering preservation of RK&M over the scale of a few hundred years, corresponding to the periods of 'direct' and 'indirect' oversight of a repository. An international mechanism is defined as an aspect of RK&M preservation that has international influence, scope or support, and is based on international cooperation. An international mechanism can be governmental (for example the agencies of the United Nations, or formal conventions between nations), or non-governmental (for example private initiatives).

A study was compiled on existing mechanisms which may be of interest for maintaining and developing oversight and for keeping memory in the short and medium term [6]. The aim of this study was to identify key questions to be addressed for the elaboration of a mechanism dedicated to RK&M for radioactive waste management. This analysis shows that international mechanisms can contribute significantly to the preservation of RK&M. To this end, a few promising mechanisms have been identified during the course of the project, for example the UNESCO *Memory of the World Programme* or the IAEA *INIS database*.

Markers

The RK&M project defines markers as long-lasting objects, placed strategically at or near the site for immediate recognition, or for discovery at a later time. These objects would be designed to inform future generations in the medium to long term. Any marker should be conceived to be immobile, robust, and provide messages that are likely to be understandable across generations. A marking system can range from a simple stone to a contrived and monumental multi-component system.

One of the guiding principles of the RK&M project is that future generations have the right to be informed. Therefore markers, if used, should be part of a concerted effort to help preserve RK&M for future generations, rather than to instill fear. Depending on their material, structural design and intended time scope, the information that markers are intended to carry can range from 'this is man-made' to much more elaborate technical content.

The integrity of markers depends on the durability of the materials used in the environment where they are deployed, including for instance extreme natural events, or acts of vandalism. In order to maximise durability, material choice should be adapted to the natural environment and/or use non-recyclable and non-reusable materials. A wealth of ideas, technologies and materials has been proposed for markers, both on the surface and underground, including berms, magnets, radar reflectors, small ceramic tokens, tracers, acoustic signals and coloured backfill materials.

It is clear that markers could attract attention and stir curiosity in an undesirable way. Therefore, a well-designed marking strategy should take account of this mechanism, and seek to minimize the potential negative effects. In any case,

markers should not to be considered in isolation, but integrated into a comprehensive RK&M preservation strategy.

In addition to deliberately placed markers, the 'archaeology of landscapes' has also been proposed through the RK&M initiative. Residual surface features such as bund walls built to preserve visual amenity, altered water courses or access routes for road and rail were noted to leave scars on the landscape, representing visual clues to previous activity.

At present, the use of markers is stipulated in legislation in Switzerland and in regulation in the United States. In Switzerland it is required that a '*repository be durably marked*'. In the USA, federal regulations on passive institutional controls state that developer applications '*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 ...*'. To date, no other country legally requires marking of the repository for extended periods of time.

There are at present no straightforward, conclusive answers to the objectives, messages and methods of marking. It is acknowledged that even if markers remain intact and traceable over time, future neglect or misunderstanding of their message cannot be ruled out.

Time capsules

A time capsule is a purpose-built, sealed enclosure containing a historic cache of records to be used as a means to inform future generations at a specified time or upon inadvertent discovery. The RK&M project considers that time capsules could be seen as a distinctive category of historical record preservation, which strongly supports and complements archives and site markers. It has been suggested that surface marker systems might incorporate time capsules, and that small time capsules could be placed at depth, at or near the repository horizon. Placed strategically underground, these markers could act as awareness triggers in case of inadvertent excavation at the repository site.

Small time capsules, possibly made of the same material as the waste containers, would not constitute a significant disturbance to the system, yet they could preserve actual records, possibly miniaturized on long-lasting support materials, which would provide meaningful information to the intruder. They could even trigger a new campaign of oversight.

Embedding time capsules in important cultural settings, coupled with their public opening at certain specific times, also suggests that time capsules can become part of cultural heritage. Indeed, 'millennial time capsules' were conceived through a process that requires important resources, new scientific thinking, and involves society [7]. The RK&M project is still developing the concept of the 'millennial time capsule', by exploring organisational requirements.

The concept of the 'dual-time' time capsule, as exemplified by the Osaka Castle time capsule, with planned life of 5000 years [8], is also being explored. 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. The time capsule was designed to address several challenges, in that it is:

- a cultural object placed in a culturally protected ground
- designed to withstand natural phenomena
- unobtrusive, being signposted through a ceremonial plaque
- very heavy, preventing easy removal
- replicated in various places, helping to propagate memory.

The opening of the Osaka Castle control capsule at regular intervals provides the basis for a ritual. It also provides the opportunity to apply the most recent preservation techniques for improving the longevity of artefacts, and potentially arresting or reversing their degradation.

As noted in the discussion for marking, it is acknowledged that there is at present no clear way forward on the potential use of time capsules as part of an RK&M strategy. Even if they remain intact over time, future misunderstanding of their content cannot be ruled out.

Oversight provisions

As noted previously, 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. Therefore the concept of oversight provides a useful framework to view technical monitoring activities and societal engagement as parts of a unified whole. These activities cannot be conducted effectively without information relating to the disposal site, so the preservation of RK&M is an essential part of future societal oversight of the repository.

Oversight can be exercised through monitoring of technical parameters and through analyses of those data. It can also be exercised through monitoring of institutional provisions meant to be protective of the repository (e.g. land withdrawal provisions established by law). Additionally, oversight can be exercised, in a broader sense, through monitoring agreements made with the local hosts. In every case, oversight is carried out by people and/or institutions. These may include the regulator, the implementer, local, regional and even international bodies, under a variety of arrangements.

The implementation of a disposal project should be viewed as an incremental process, with different phases, in which there is a gradual transition between various forms of oversight during the pre-operational, operational and post-operational phases. Planning for oversight, both direct and indirect, should start when the siting procedure begins. In order to design an optimal approach to oversight, it is important to harmonise social and technical demands. Therefore, involving local and regional stakeholders as part of a well-designed oversight process, from the beginning of the disposal project, will encourage strong links between the local and regional populations and the repository.

REDUCED RECORD SETS

In order to address concerns about the volume of records generated by a national radioactive waste facility, the RK&M project has defined the concept of a reduced Set of Essential Records (SER), with further reduction to a Key Information File (KIF), for long-term retention. The KIF in particular is anticipated to be central to the success of an RK&M strategy. The reduction in scale of the records opens the potential for the production of more copies and the use of more durable materials. This should improve their accessibility and longevity.

Set of Essential Records

The RK&M project is still developing the concept for the SER, but it is intended that this should be the smallest set of records that gives a helpful overview of the repository system, its contents and, possibly, the means to verify its performance. Although there are no direct examples of a developed SER, a TECDOC published by the IAEA provides some useful context [9].

The content of any particular SER is expected to vary according to national regulations and legal requirements. Similarly, complementary sets of records could be identified as essential by different stakeholders. Whatever they consist of, the reasons for choosing the SER should be explicable and justifiable. Future societies, rather than individuals, are the target recipients of the information. However, rather than using guesswork to decide what a possible future society may want to know, the SER is being developed in the light of current societal information requirements.

Key Information File

The KIF would provide a summary of the existence, location and content of an engineered facility for the permanent disposal of radioactive wastes, and should be recognized as part of an internationally integrated system of records and memory. Its primary function would be to provide an enduring memory of the site, and long-term confidence in the effectiveness of the disposal system, so that the likelihood of unnecessary human disturbance is minimized. In order to allow diffusion of this document to a large audience, its size would be severely limited. It would be part of the information system related to the repository.

Early development of the KIF concept is being trialled through preparation of draft documents for the WIPP at Carlsbad in the USA (deep geological disposal), the planned final repository for spent nuclear fuel at Forsmark in Sweden (deep geological disposal) and the Centre de la Manche facility in France (surface disposal) [10]. Other disposal facilities, both under development or in planning, are invited to 'road test' the products and provide feedback.

REPORTING PLANS

As currently conceived, the NEA RK&M project will draw to a conclusion at the end of Phase II, in April 2018. At this point, the work will be reported, so that national disposal programmes can start to make use of the information. Information will be made available via both traditional reporting structures and web-based platforms.

The broad scope of the work of the RK&M project does not define a reporting structure. A number of options have been identified, and developed to concept status. These options will contain some common features, and the chosen approach will be developed to cover the full scope of work undertaken by the RK&M project. A format based on time evolution would place the emphasis on an evolving system, consistent with the anticipated development of oversight provisions.

Further refinement and maintenance of the RK&M project outputs and concepts is desirable. The NEA is committed to ensuring the continued accessibility and availability of the project outputs into the future.

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