Analysis of the Needs for Long Term Memory and Knowledge Preservation Relating to Radioactive Waste Disposal Facilities – 17213

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ABSTRACT

Proposals for a set of provisions for long-term memory and knowledge to be defined for a radioactive waste disposal facility, near surface or deep underground, address two primary motives, related to two ethical principles. The first motive is to prevent future generations from interfering involuntarily with the repository. This requires maintaining awareness of the repository, and addresses the ethical principle of protection of man and environment. The second motive is to provide future generations all the available relevant information which might help them make informed decisions about intentional actions, and assess the consequences. This requires transmitting detailed knowledge of the repository, and addresses the ethical principle of preservation of freedom of action. The set of provisions to be implemented with respect to each of these motives may not be the same.

In order to define and assess the set of provisions, it is also useful to identify the various components of the process of transmission of a given message, or set of messages, to future generations. Three sub-processes have been identified: (i) 'memorization', at the producer stage, where a full set of information to be transmitted is identified, organized and expressed; (ii) 'preservation', where the potential durability of records is extended, the preservation conditions are controlled and where the records may be restored, if their status is degraded; (iii) 'access', at the receiver stage, where the receiver has to be notified of the existence of the information, to find it and to interpret it properly. As a failure of transmission to future generations would result from the failure of any of the sub-processes, a minimal set of provisions may be defined from this decomposition.

INTRODUCTION

Facing the issue of memory and knowledge preservation for radioactive waste repositories, a lot of work has been devoted in various countries and internationally. In France for example, Andra launched in 2010 an ambitious "Memory Program", with research actions in fields as diverse as semiotics, materials science and landscape archeology, together with the upgrading of the "memory reference solution" already implemented for the Manche surface repository [1]. At the international level, an initiative, Preservation of Records Knowledge and Memory (RK&M) across Generations, was launched in 2011 under the auspices of the Nuclear Energy Agency of OECD [2]. It was, for its second phase, converted into an expert group, which will continue until April 2018. The work of the RK&M expert group is now focusing on the characteristics of the set of

memory provisions to be implemented [3][4][5]. The authors of this paper, who are all members of this expert group, wish to share some reflections on the basic needs that underlie the definition of such memory provisions.

MOTIVATION FOR LONG TERM AND MEMORY PRESERVATION

The motivation for preservation of memory and knowledge can be expressed as two primary aims: the first is to prevent inappropriate actions that could disturb the repository; the second is to support a possible decision of intervention. An additional motivation is to transmit to our descendants the associated industrial heritage relating to waste management and disposition.

Prevention of inappropriate action

Prevention of inappropriate action is related to the long-term disposal safety. This is to ensure that human actions do not disrupt the protection properties of the repository, either by intrusion into the disposal cells (which provides the default of the isolation function) or by disruption of the local environment / host rock (which provides the default of the containment function). This motivation is related to the concern for the protection of future generations, which derives from the general ethical concept of avoiding harm to other living beings [6][1].

In order to address this aim, it is necessary to maintain an awareness of the repository [7][2], for as long as it constitutes a risk for man and environment. The amount of information that needs to be transmitted to achieve this aim is quite limited:

- Delimitation of the area (which will support locally defined easements)
- Global inventory and its evolution in time (in order to help determine when easements may be reduced)
- General presentation of the repository (to satisfy curiosity and prevent any anticipation of "hidden treasure")
- Overview of the safety case, and the impact of the facility in normal operation (to avoid raising disproportionate concerns), and
- Presentation of risks in case of untimely action (to ensure that the consequences of any potential action can be anticipated).

Provisions addressing this aim may be for example markers, land use control

[1] According to Buchanan [6], "the most promising approach toward building a moral foundation for intergenerational obligation is based on the simple concept of avoiding harm to other living beings".

[2] We use "awareness" with the meaning "knowledge that something exists" (Cambridge Dictionary, [7]), so "awareness of the repository" refers to knowledge that the repository exists. "Knowledge that something exists" is clearly only a part of the "knowledge of something". In order to emphasize this difference, we speak of "detailed knowledge of the repository" if we mean knowledge in its full domain, and of "awareness of the repository" if we mean knowledge of the existence of the repository only.

(easements) or the Key Information File (KIF) [5], the full scope of which is presently being developed within the RK&M expert group.

Support for a possible decision of intervention

The second aim is related to support for future decision makers who may need to intervene with the repository. This may be motivated, for example, by a desire to correct an anomaly, either proved or anticipated, or to implement a new waste management method considered more consistent with new performance criteria. If a decision concerning the repository is foreseen, the availability of information will help preparing its implementation. On the contrary, if the relevant information, though elaborated earlier, is no longer available, extra preparation costs will be incurred. This might in the end make the decision practically impossible to implement, and would reduce the resource available for other decisions. In both cases, this would reduce the scope of decisions that may be made. From the ethical point of view, providing support for a possible decision of intervention corresponds therefore to the respect for freedom of choice of future generations.

In order to address this aim, it is necessary to make available to those who will need to instruct a decision or conduct research, the key body of information on the repository that will be relevant in the long term. The need is here to transmit detailed knowledge of the repository and its context. The information to be transmitted concern in particular, in addition to those cited above:

- The context of the design and operation of the facility (in order to understand why the decisions leading to present situation were taken)
- A detailed description of disposal structures (to allow timely corrective action, for example)
- A detailed description of the inventory packages, for each disposal cell (to allow partial recovery of waste, for example, or a reallocation of items)
- Detailed data on each waste package (to allow a re-evaluation of the radiological and chemical inventory, for example)
- Details of long-term safety studies (for example, to ensure that actions taken do not disrupt the safety case for the remainder of the waste, and/or that the safety provisions can be restored after the action is completed)

Markers, land use control and the KIF may contribute to this aim, but they are not sufficient. The Set of Essential Records (SER), which is also being developed within the RK&M initiative [5], aims at addressing this issue.

Transmission of industrial heritage

A third aim for memory preservation is to allow future generations to benefit from the experience and knowledge that have been developed by current society in the process of waste management. This does not mean that they could need it for decisions related to the repository: even if the repository is left as it is, it will be useful in the future to know how our society dealt with the issue of radioactive waste management. In a similar way, the memory of ancient mines, or more generally ancient industrial activities, is now considered worthy of retention, as a part of our cultural heritage [8]. However, the strength of this motivation is lower than for the two other motivations, which are related to decisions regarding the repository. This third motivation will not be investigated in this paper, at least partly because the provisions implemented in order to address the other

motivations contribute to addressing the third one. In any case, provisions addressing this third motivation will contribute to maintaining awareness of the existence of the repository and in some cases to providing detailed knowledge of the repository.[3]

OPERATIONAL GOALS FOR INFORMATION TRANSMISSION TO FUTURE GENERATIONS

From the three aims presented above, two operational goals have been identified: maintaining awareness of the existence of the repository and providing detailed knowledge of the repository. Table 1 compares the parameters for both goals.

In this table, the item "factor of obsolescence of the issue" deserves further comment:

The mention of the discount rate points to the fact that the obsolescence of the need for detailed knowledge of the repository is also governed by the balance between the committed accumulated costs incurred to ensure detailed knowledge preservation, versus the potential for one-time costs incurred for knowledge reconstruction in case of a decision to be made and implemented. The discount rate is used by economists to take account of the time dimension when calculating this balance of costs incurred at different dates. The issue of the discount rate to be considered raises ethical questions, which have been raised by A. Van Luik and others [9].

Similarly, techno-scientific evolution may change the need for detailed knowledge, by introducing new abilities, which would make it easier to reconstruct lost knowledge. This would be the case for example if new in situ characterization techniques were developed.

Consequently to this balance between physical (radiological) and human (economical and techno-scientific) factors, it may be noticed that depending on the wastes and on the repository design, the minimum duration of the preservation to be achieved with respect to the two goals could differ. For example:

- On the one hand, if the initial radiotoxicity of the disposed waste is low and decays rapidly, the issue of protection of man and environment might vanish after a few centuries, whereas an issue of re-use of the site or of some disposed material might appear. This case may be expected with surface repositories.

[3] Knowledge of this industrial heritage can be transferred to future generations by means of elements of cultural heritage. The cultural heritage consists on the one hand of tangible heritage such as monuments, man-made landscapes, books, works of art and intangible heritage such as traditions, folklore, events…

Table 1 The two operational goals underlying memory provisions

	Awareness of the repository	**Detailed knowledge of the repository**
Motivation for transmission	Prevent inadequate decision-making regarding the repository	Support a properly informed decision regarding the repository
Ethical ground	Protection of man and environment in the future	Preservation of freedom of action for future human generations
Issue (what is at stake?)	Radiological and chemical impact on man and environment in the future	Conditions and cost of the implementation of an intervention decision in the future (for example related to preliminary characterization)
Factors of obsolescence of the issue	Radioactive decay	Radioactive decay Techno-economics : discount rate, techno-scientific evolution
Primary message to be transmitted	Caution: do not disrupt the repository safety functions	Care: intervene if you must but do so with knowledge of the hazards and information to restore the safety provisions
Amount of information to be transmitted in support of the message	Minimum that is necessary to deter an inappropriate action: - Delimitation of the area - Radionuclide overall inventory and its evolution over time, - General presentation of the repository, - Overview of the safety case, the environment impact for an undisturbed repository - Presentation of risks incurred in case of inappropriate action.	Maximum that is reasonably possible to assist in the instruction of a future decision, including: - Context of the design and operation of the facility - Detailed description of the repository structures - Detailed description of the waste packages, cell by cell - Detailed data on each package - Details of long-term safety studies
Target / objective for information accessibility	Large audience, educated or not (diffusion as wide as possible, locally) / Easily understandable, both now and in the future	People in charge of decisions related to the repository / Easy access to an educated person, to relevant information in the mass of information available
Need for robustness of transmission provisions	Maximum (regards survival, or at least health, of the affected persons)	High (regards quality of life of the interested persons)

- On the other hand, for high level wastes disposed deep underground, the issue of environment protection will last for millennia[4], whereas the issue of detailed knowledge preservation could vanish after a few centuries.

THE SUB-PROCESSES REQUIRED FOR INFORMATION TRANSMISSION

In order to define and assess the set of provisions, it is also useful to identify the various components of the process of transmission of a given message, or set of messages, to future generations. It is therefore proposed to describe the long-term transmission process as a combination of three sub-processes:

- A "memorization" process, where the information to be transmitted is elaborated using existing records and knowledge, and expressed in a way that maximizes the potential for understanding and appropriation by future generations;
- A "preservation" process, the role of which is to convey information from the present generation to future generations; this process may rely on relay from one generation to the next or direct transmission based only on the durability of the record;
- An "access" process, which is designed to ensure that the intended targets are aware that information is available for them, that the relevant information corresponds to their needs, and that they can interpret it correctly.

Each provision may thus address only a part of the whole transmission process, but all the components should be covered by the whole set of provisions. This is one aspect of the systemic approach recommended by the RK&M initiative[5], another aspect being to provide redundancy of the provisions for enhanced robustness.

The memorization sub-process

The memorization sub-process draws upon the initial raw information that is available (from observation, measurements, modelling, reflections, etc.), to elaborate the structured documents that have potential for transmission.

This means first identifying the information deemed relevant for transmission, by collecting the available information, and identifying the information worthy of being selected. Contextual information, not necessary for the current operations of the repository, but which may be essential in the future to understand why things are

[4] Therefore it is very important to have a good embedding of the awareness of the repository with the local/regional population because institutions (and their control) might not last "forever" (budget cuts, state disruption….)

[5] The RK&M expert group defines this as follows: "A systemic approach should be formulated whereby the various components of the RK&M system complement each other, provide for redundancy in the communication of messages and maximise the chances of survival of a recognisable and comprehensible message." [2]

as they are, may also be identified.

Secondly it means organizing the selected information in a way that will be accessible by future users. For example, for a single document such as the Key Information File (KIF), the concept of which is being developed by the Records Knowledge and Memory preservation (RK&M) expert group [4], this implies defining the structure of the document and distributing information between the various chapters. For a set of documents as the Set of Essential Records (SER), the concept of which is also developed within the RK&M expert group [5], this implies providing tools that will help future readers to find their way through the mass of information they will have available, such as: a listing of documents, a structure for the set of documents, or more elaborate search tools.

Finally, this means expressing the information into a record or set of records: writing the report according to presentation rules in force or constituting the set of documents and implementing it in an information system.

The steps of the memorization sub-process, though presented here sequentially for convenience, may be partially conducted in parallel and with iterations.

The preservation sub-process

The preservation sub-process relates to propagating existing records through time. It may be also decomposed into three components: extending potential durability, controlling the preservation conditions and restoring possibly degraded records.

The first component of preservation is extending the potential durability of preservation: the supporting media initially used, electronic files or normal paper, may be sufficient for transmission over a short period of time, years or decades, but not adequate for longer term transmission. Therefore, documents may be transferred on durable materials (permanent paper, sapphire discs, etc.) and entrusted to archiving institutions (in the case of records such as those selected for the SER), who will be in charge of preserving them. Similarly, the migration of a database into a new version of a database management system extends its potential durability.

A second component is controlling the conditions of preservation: this may be performed by institutional curators such as archiving institutions or museums (active management). Another possibility is to rely on the intrinsic durability properties of the supporting medium and isolation from environmental conditions and human actions (passive management): this would be the case for subsurface markers, for example.

The third component is restoring degraded records, after an evaluation of their conservation status. This would be facilitated by the availability of information besides the degraded records, either in duplicated similar records stored elsewhere, or as part of other records. For example, drawings and photographs of a destroyed monument help rebuild it close to its initial state.

The access sub-process

Once the records have been elaborated by the current generation, then propagated through the ages, there is still a necessary sub-process: that is access to the information. The receivers of the information, the “targets”, must first be aware

that information exists, then find the proper information they need, and finally interpret it correctly.

The first condition for access is being informed. Numerous examples exist in the construction industry of information being properly elaborated and preserved, but not used, sometimes with dramatic consequences, because people simply didn't know, or take the trouble to find out. This refers to the role of markers and land use controls, which are designed mainly to alert and point to more detailed information. This step of the access sub-process leads to requirements, for the "expression" component of the memorization sub-process.

Another condition for access is finding the proper information from the whole set of information available. When confronted to a question related to the repository, the recipient of the records will need to find the answer from the mass of available information. If not prepared properly, this may be equivalent to finding a needle in a haystack. Therefore this step of the access sub-process leads to requirements, in terms of legibility of the structure, or "user-friendliness" of the guiding tools, for the organizing component in the memorization sub-process.

The last condition for access is interpreting correctly. This requires that words are understood with their original meaning, despite possible shifts in meaning. This requires that the context of the elaboration of the document is sufficiently clear to the reader to avoid misinterpretation. This step of the access sub-process leads therefore to requirements, in terms of completeness of glossaries and tables of acronyms, of description of the implicit context of decisions, for the "identifying information" component of the elaboration sub-process.

Figure 1 summarizes the decomposition of the transmission process described in this section. The pink arrow of the preservation sub-process symbolizes the intrinsic dimension of time-dependency for this sub-process, unlike the other sub-processes.

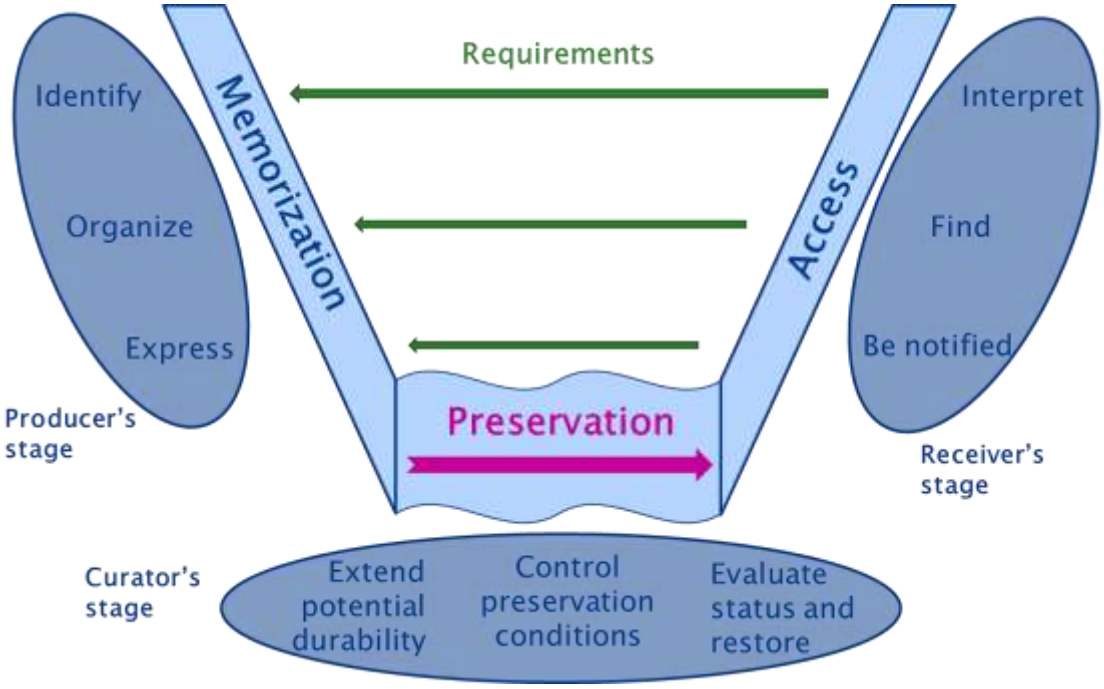

Figure 1 The information transmission process to future generations

THE SPECIFICITY OF INFORMATION TRANSMISSION TO REMOTE GENERATIONS

Information transmission from a producer to a receiver always implies the components described in sub-process "memorization" and "access". However, although there may usually be feedback from the receiver to the producer, which allows refurbishment of the documents, future generations will not have the possibility to come back to us complaining about information gaps or asking the meaning of obscure formulations.

This emphasizes the importance of reviews that help to assess how a future receiver would deal with the records that we intend to transmit, taking account of the evolution of society from the date of emission of the documents. Reviews may lead to an upgrading of the document or set of documents, e.g. by introducing in the glossary new definitions for words which seemed obvious earlier, or new documents recalling the context of the decisions that were made in the past.

Moreover, the issue of records preservation is enhanced when producer and receiver belong to remote generations. This introduces a third type of actor, besides the producer and the receiver, here called the curator. In this context the curator's role is to facilitate the time-dependent preservation of information - it does not refer necessarily to an institutional curator such as an archiving institution.

CONCLUSION

Three reasons have been identified for knowledge and memory preservation of a radioactive waste repository. The first one aims at preventing an inadequate

decision related to the repository, the second aims at supporting an adequate decision related to the repository, and the third one aims at providing information, even if no decision is envisioned. They are addressed by two operational goals: maintaining awareness of the repository and transmission of detailed knowledge of the repository.

The set of provisions to be implemented with respect to each of these goals may not be the same. For example, the Key Information File (KIF), the definition of which is presently being developed within the international initiative "Preservation of Records, Knowledge and Memory (RK&M) across Generations", co-ordinated by the Nuclear Energy Agency (NEA), is focused on the first goal; the Set of Essential Records (SER), which is also being developed within the RK&M initiative, is more focused on the second.

Analyzing the transmission process of information to future generations, three sub-processes have been identified, called in this paper "Memorization", "Preservation" and "Access", each of them schematized in three components, resulting in a total of nine components.

The RK&M expert group recommends that a systemic approach should be formulated whereby the various components of the RK&M system complement each other, provide for redundancy of message communication, and maximize the survivability of a recognizable and comprehensible message. One aspect of this systemic approach is to provide redundancy of the provisions for enhanced robustness. Another aspect, introduced by this publication, is that an efficient set of provisions for the transmission of information should address the nine components of the scheme, along with the two operational goals pursued according to the repository and the wastes.

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