

## **Preservation of Information and Communication With Future Generations – 14509**

Erik Setzman  
Swedish Nuclear Fuel and Waste Management Company (SKB),  
Box 250, SE-10124 Stockholm, Sweden

### **ABSTRACT**

Nuclear waste management is a complex, controversial and challenging field of work. In addition to the obvious need for safe technologies and sites issues like acceptance, trust and confidence must also be treated seriously in transparency and with greatest care. The Swedish spent fuel final repository project is now moving from research, planning and preparations towards decision making, construction and operation. The topic of keeping records, knowledge and memory about the planned repository for future generations gets more attention than earlier. It must be approached both professionally, from a broad scientific base, and with human humbleness. Questions and discussions about if, when, how and by whom this could or should be done are becoming more and more frequent even beyond the established circles. This is a new experience which requires our attention. It also indicates opportunities to reach new groups of people or individuals, both professionals and others, that may contribute positively in our continued efforts.

SKB has since the early 1990's, with successively growing interest and understanding, been studying how to find ways to avoid inadvertent human intrusion and how to give future societies the ability to make their own well informed decisions about then existing final repositories. We are convinced that this shall continue to be main targets. Strategies and principles can preferably be identified and developed in international cooperation. A framework of basic principles, guidelines and a plan for redundancy of archives as well as continued exchange of ideas, experiences and good examples would be appropriate and useful in the short term. It is essential that the proposed continuation of the Nuclear Energy Agency of the OECD (NEA) project on preservation of "Records, Knowledge and Memory" (RK&M) gets strong support in order to secure approval during 2014. Proper measures and solutions can then be identified, developed and decided by each country and waste management programme in due time before the end of operation and closure of repository facilities. Based on these conclusions SKB's focus in the very short term lies on strategy development, support to and participation in international cooperation, continued preparation of documentation and records, some specific research projects in priority areas and spreading and increasing knowledge about the topic in general, especially to new target groups. Such target groups that have recently been or are currently approached specifically concerning this topic are for example the host municipality, young people; human, societal and nature sciences; decision makers and media.

### **INTRODUCTION AND BACKGROUND**

#### **Radioactive waste management in Sweden**

SKB, founded in the 1980's by the owners of the nuclear reactors in Sweden, has for more than 20 years been operating a final repository for short-lived radioactive waste (SFR) in Forsmark and a central interim storage for spent nuclear fuel (CLAB) in Oskarshamn Sweden. In addition SKB applied in early 2011 for the necessary licenses to establish a final repository for spent fuel in Forsmark after more than 30 years of research, development and siting. In recent years,

memory keeping, including for example both archives and markers, has become a topic of increasing interest and attention among stakeholders and media.

### **Previous work on preservation of information**

In 1990 a working group of the Nordic nuclear safety program (NKS) was formed and given the task of establishing a basis for a common Nordic view of the need for information preservation for nuclear waste repositories. The group investigated what type of information that should be conserved, in what form the information should be kept, the quality requirements on the information and the problems of future retrieval of information, including retrieval after very long periods of time. Topics covered included the following: scientific aspects including social context of scientific solutions, information management, systems for conservation and retrieval of information including the problems of prediction, archives, markers, archives versus markers and continuing processes in society. Archive media including paper documents, microfilm, digital media and media lifetimes were also covered [1, 2].

SKB started to study the topic of preservation of information and communication with future generations in the early 1990's [3, 4]. The work was resumed again more purposefully some years ago during the preparations for the spent fuel repository applications and ongoing licensing procedures. From SKB's point of view this is a challenging topic without simple solutions that must be approached professionally with a humble attitude. Solutions can preferably be identified and developed in international cooperation, at least concerning principles, guidelines and redundancy of archives. A natural starting point when resuming work on the topic was to try to get an overview of similar topics in other fields and of current status concerning the topic within radioactive waste management programmes in other countries. Except from a number of studies and concepts originating from the Yucca Mountain and the Waste Isolation Pilot Plant (WIPP) projects in the United States rather few documents on the topic were at that time produced or well known. It became obvious that a wider search to gain experiences from other fields and more international activity and cooperation on the topic had to be promoted and initiated. The ultimate aim is ensuring and facilitating that records, knowledge and memory about the repositories for spent nuclear fuel and waste can be preserved and transferred to future generations in order to make it possible for them to make their own informed decisions and avoid inadvertent intrusion.

A number of tangible measures and guidelines for information preservation and transfer, in the short and long term, were identified and discussed in two separate studies. The study reports deal with a number of aspects relating to information preservation as well as risks that can lead to the loss of important information. The first report is based upon identified key documents, interviews with key persons, and other relevant sources of information. It summarises the work done in the field of knowledge preservation regarding a repository for spent nuclear fuel in Sweden and in other selected countries [5]. The second report covers the basic principles and methods for information preservation and transfer, and briefly describes their advantages and disadvantages. The report covers topics such as time perspectives, target groups and context. It also discusses the differences between the concepts of information or knowledge [6]. Some recommendations for further work are the conclusions. The main emphasis is on practical measures that need to be carried on or implemented in the near future to pave the way for and to ensure that successive and direct information transfer is handled in a suitable manner, including:

- Designate a person responsible for information preservation.
- Work out guidelines for information preservation and transfer.
- Form a network with other organizations in Sweden.
- Initiate a dialogue with other countries and implementers in a similar situation.
- Participate in seminars, conferences and workgroups and projects on an international level within the IAEA and the Nuclear Energy Agency (NEA) of the OECD.

### **Legal requirements and regulations**

Existing Swedish requirements and regulations of relevance are from The Swedish National Archives (RA) and The Swedish Radiation Safety Authority (SSM). They are rather general and concentrated on technical documentation, archiving and keeping of records. For instance markers and communication with future societies and generations are not specifically regulated. The most relevant requirements and regulations are the following:

RA-FS 1997:3. The RA regulations and guidelines for planning, implementation and operation of the *premises for archives*. The three central archives at SKB (Stockholm, Forsmark and Äspö) fulfill these regulations.

RA-FS 2006:1. RA's regulations and guidelines for *paper documents*. Regulations governing the production, handling, keeping and delivery of documents on paper. Cover all SKB's facilities and activities.

RA-FS 2009:1-2. RA's regulations and guidelines for *electronic documents* (recordings for automatic processing). Regulations governing the production, keeping and delivery of electronic documents. Cover all SKB's facilities and activities.

SSMFS 2008:38. SSM's regulations on filing at nuclear installations. Requirements for proper filing, archiving and long term preservation of *radiation protection documentation*. Cover all SKB's facilities and activities.

SSMFS 2008:1. SSM's regulations and guidelines on safety at nuclear facilities. Requirements for long term preservation of *technical documentation*. Cover all SKB's facilities and activities.

### **Other drivers**

"How to secure the information preservation about the facilities for future generations" became a rather frequently asked question (FAQ) during environmental impact assessment (EIA) and public consultations before preparation and submission of the permit applications for the spent fuel final disposal facilities. Entering the ongoing review and licensing procedures has increased and broadened the interest in and focus on this topic even more both within the licensing procedures and outside. SKB as implementer, the regulator SSM and the Swedish National Council For Nuclear Waste are not the only ones thinking about the topic, any more. This is clearly shown by activities and comments from stakeholders like the planned host municipality of Östhammar and the Non-Governmental Organisations (NGO:s) as well as increasing public awareness and media coverage.

## CURRENT STATUS

### Overview

For long term information transfer, one strategy links information through successive transfers of archived material and other forms of knowledge in society. Another strategy, such as marking the site with a monument, relies upon a direct link from the present to the distant future. Digital methods are not recommended for long term storage, but digital processing may be a valuable tool to structure information summaries, and in the creation of better long lasting records. Advances in archive management should also be pursued to widen the choice of information carriers of high durability. For the moment SKB carries through or participates in a variety of activities in order to promote and facilitate improved knowledge and widened discussions. An important aim is also to try to spread the knowledge and discussions about the topic as much and as far outside the inner circle as possible to get wider understanding, interest and involvement on how to meet the unique challenges of communication with a distant future. At present SKB is engaged in the following activities:

- “Archaeology meets radioactive waste”, a research project about what we can learn from the archaeologists, in cooperation with the Linnaeus University in Kalmar, Sweden.
- “Significance of the language”, how to make messages as understandable as possible over time, a recently initiated joint project with the university of Lund Sweden.
- Bilateral agreement with French waste management agency ANDRA on joint efforts, research and exchange of knowledge and experience.
- Active participation in the “Preservation of Records, Knowledge & Memory Across Generations” (RK&M) international project of the OECD/NEA [7].
- Contacts with the National Archives of Sweden (RA), the regulator (SSM) and other national actors on proper archiving procedures and formats as well as for example e-archiving.

Some of the identified challenges to be faced and questions to be discussed and studied in order to avoid inadvertent human intrusion and to give future societies the ability to make their own well informed decisions about what to do are for example:

- What information should be kept, where and how?
- What languages should be used?
- How to achieve international redundancy of archives?
- Potential role and design of markers?
- Possibilities to involve locals and the host municipality without inducing new or further responsibilities on them?
- How to find persisting ways for knowledge transfer from generation to generation?
- How to secure the necessary resources to finance this?
- When should an “Information preservation plan” for a nuclear facility be requested, required and presented?

Target groups that have recently been or are currently approached specifically concerning this topic are for example the host municipality, young people; human, societal and nature sciences; decision makers and media. Measures of interest for further studies in this field might be such as local archives and museums, design and maintenance of markers and monuments, continuously returning school and education topics, monitoring and other possible events or rituals for transfer of knowledge and memory keeping.

## **Documentation and archiving**

An Information Management Plan is issued for all activities that initiates, produces or receives documents or data of importance. The plan governs the handling of documents and data until the filing and is an aid in the daily management of information. It provides information on what documents and data that can be sorted out, what should be kept and for how long. SKB files all data and relevant information as long as our facilities are in operation. After closure when the final repositories are sealed and facilities on the surface are no longer in use, information of the location of the repositories and their contents is planned to be preserved.

Documents are kept in hand archives or in intermediate archives as long as they are in production or in use. What type of archive to be used is set in the Information Management Plan covering the document. From these archives are the documents subsequently transferred to one of our three central archives for filing, for the time set in the Information Management Plan. SKB's central archives are constructed according to the Swedish National Archives' regulations and guidelines concerning the premises for archives (RA-FS 1997:3), in order to protect the documents and records against destruction, damage, theft and unauthorized access. In SKB's central archives only analogue documents and information on CD/DVD are normally filed. In the central archive at the central interim storage for spent nuclear fuel (CLAB) are also documents on microfilm ("photo cards") and X-ray film filed. Information received in other formats is transformed to the prescribed formats.

Documentation on non permanent paper that may become difficult to read because of age, shall be transferred to a new information carrier before defects occur. At the transfer it must be ensured that the information is reproduced accurately. To ensure the quality of the information on CD/DVD each CD is migrated, burned again and replaced with the latest edition, every fifth year. All this is done according to ISO 9660 (CDFS – Compact Disc File System). Most of the archived material is in Swedish but there are also a large number of reports in English.

When SKB's activities ceases shall all archives, arranged and listed, be submitted to the Swedish National Archives according to both internal demands and the requirements of the regulator, The Swedish Radiation Safety Authority (SSM). Since the national borders may change in the time scale relevant for nuclear waste, the creation of a redundant international archive system for information and records about all repositories and radioactive wastes, based on more than the current safe guard requirements, would represent an improvement as regards securing conservation and retrieval of information and records.

## **Language and understanding**

A recently started study "*Ancient texts in ancient tongues – nuclear waste and future knowledge*" approaches the topic of language changes over time and the potential for future generations to understand texts and messages in our existing languages that will then become ancient languages. The study will be carried through for SKB by Ola Wikander, PhD (Old Testament Exegesis/Hebrew Bible), at the Lund University in Sweden.

During the approximately 5,000 years that the human species has been able to record its words and ideas in writing, a vast corpus of textual material has been created, that can teach us something about how our human species has been successful – and, perhaps even more importantly – how it has been unsuccessful – in preserving complex information for future generations.

Initially two areas of inquiry will be the object of preliminary studies in article form. The first one will discuss cases of failed or drastically reinterpreted preservation of textual and in some cases technical information from the ancient world. Examples such as the religiously motivated warnings against opening Phoenician sarcophagi, the importance of the choice of writing materials (clay tablets, vellum, papyrus, etc.), more purely technologically oriented cases of failed transmission of knowledge such as the so called Antikythera mechanism, the role of intellectual elites (in this historical context, often religious intellectual elites) in preserving large bodies of textual material, etc will be analyzed. A second article will concern another sphere of questions, focusing more specifically on the challenges posed by language change, political and economic impacts on language use, and other questions of similar kind.

The time frame of nuclear waste management stretches tens or hundreds of thousand years forward in time, almost into infinity. The textual history of the human species is only a fraction of this, but we must take what we know of this history into consideration when considering how to preserve vital information for coming millennia. From clay tablets to DVDs, the history of human communication needs to have a bearing on our communication with the future, and illustrating this need – and drawing conclusions from our textual and linguistic history – constitutes the aim of the present study.

### **Markers, archaeology and landscape**

In the Nordic countries, during the first few thousand years, monuments at a repository site may be used to warn the public of the presence of dangerous waste but messages from such markers may pose interpretation problems as we have today for messages left by earlier societies such as rune inscriptions.

“One hundred thousand years back and forth - Archaeology meets radioactive waste” is a current SKB project carried through by the Linnaeus University in Kalmar Sweden. The project has two main aims. The first aim of the project is to contribute to SKB’s task of finding a viable communication strategy for conveying the risks of nuclear waste to human beings in the long term. The basis is drawing on the experience with communication strategies and other future related policies in the heritage sector and in the field of history pedagogy together with an investigation of the archaeological understanding of long term time perspectives. A second aim is to contribute to contemporary heritage studies with a novel perspective investigating understandings and practices in relation to the future.

From this, some interesting parallels between archaeology and nuclear waste management can be drawn, both

- are dealing with long time periods – i.e. 100 000 years backward / forward,
- engage with material culture and specific sites – material properties are significant,
- give meaning to rubbish from another culture – rubbish reflects the conditions from which it originates,
- are seeking to preserve some heritage and associated knowledge – ideally “in situ”, supported by documentation,
- are working today for the sake of future generations – responsibility for precious object (non-renewable versus non degrading) and
- are creating confidence that past and future are manageable – credible stories about the experts’ own abilities are important.

The project will seek to establish the case of nuclear waste as a central example for discussing future and communication issues in the heritage sector in order to provide a long term benefit both for the heritage sector and for the nuclear waste sector. A very positive secondary effect of this project is that frequent participation with presentations in conferences and seminars as well as frequent writing of articles in scientific papers has proved to be a successful way of increasing knowledge about the topic and putting it on a wider agenda than the nuclear waste agenda.

The concept of “self marking sites” is found to be of particular interest. It doesn't require instrumented surveying, has potential to persist over time and gives clues that something important is concealed or has taken place underground. Residual surface features leave scars on the landscape, and will represent visual clues to previous activity. Such features may include rock spoil or bund walls built to preserve visual amenity, altered water courses or access routes for road and rail. There are many examples where similar visual clues have existed for several thousands of years. With planning, it may be possible to engineer these into the design of new geological repository facilities. A buried structure containing radioactive waste will represent an anomaly in the environment. Excavation and emplacement is likely to reduce the density of the rock volume but increase its metal content, if metal canisters or containers are used. Thus instrumented surface based surveys may detect gravitational, magnetic or resistivity signatures.

The difficulty and complexity of the task to design messages and markers intended to communicate with and inform humans generations in a distant future requires fundamental and at the same time simple measures and solutions. There are indications implying that what is first lost, when there are no written sources of information, is the connection between a marker or an artefact and what it represents. The rock spoil from construction of the tunnels will be the only natural large scale trace and remnant from the final repositories for radioactive waste and spent nuclear fuel in Sweden. Because of this the rock spoil ought to be regarded as a valuable potential asset for a marker. Kept in manmade non natural formations on the surface above the repositories it might support and send a message to communicate to future generations that something extraordinary has taken place just there. Even if future glaciations and ice ages will limit the existence of such a marker in Scandinavia it could exist for thousands of years and play an important role [8].

In addition to “self marking sites” and manmade markers on the surface above and around repository facilities possibly the concept of underground markers should also be considered and evaluated. This could mean texts or signs on individual waste canisters or packages or other kinds of markers and messages left when refilling and closing tunnels and shafts.

### **Spreading awareness and promoting discussion**

About 10 years ago SKB launched a quite ambitious programme with a specific web page as a base which was named “Underground” aiming to test communicating on the Internet and to increase the interest among young people for final disposal of radioactive waste. An important part within the framework of this programme was a brain storming competition in the year of 2006 about markers, symbols and messages for future generations. This resulted in more than 350 suggested and envisioned designs for markers intended to be placed on the site, after closure of the spent nuclear fuel final repository. The outcome was of course quite varied. However some interesting ideas and indications were received that might be worth further consideration. The winning contributions, Fig. 1, were elected through web voting and awarded with a study trip to London and Stonehenge.

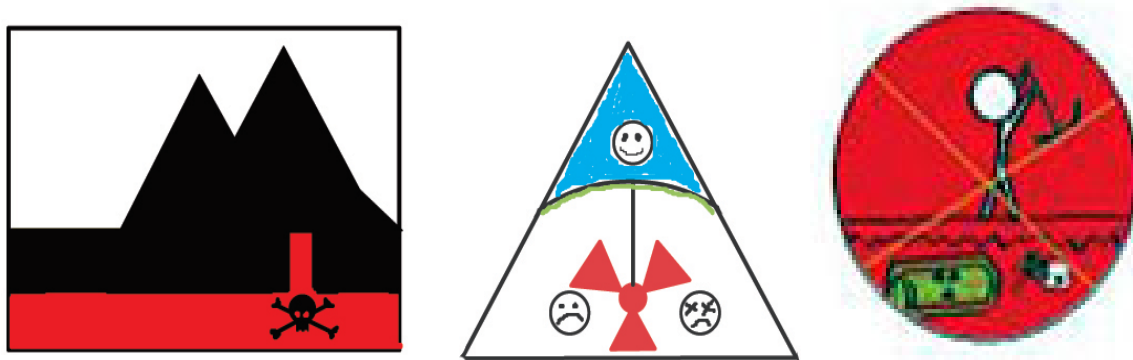


Fig. 1. The three award winning suggested marker contributions from SKB's "Underground youth project competition" in 2006.

In recent years this has also been complemented by some school and drama projects (theatre plays and artistic projects) trying to approach the topic of final disposal of radioactive waste and how to communicate with humans in a distant future from different angles. In 2012 and 2013 two different drama groups contacted SKB and presented ideas of theatre plays aiming to visualize and dramatize the field of radioactive waste disposal and the need to communicate with future societies. SKB decided to promote both groups, to follow their work and to evaluate the results. The first of these two cases "Young Scene East contacts the future" was produced as a school theatre play. It was described as "an interactive science fiction documentary" with survival of the earth as main theme. In addition to dealing with green house effects, global warming, melting ices and vanishing species it also dealt with problems and risks connected to radioactive waste disposal. About 25 performances were made for elementary schools and secondary schools (pupils aged 13-19) in the cities of Norrköping and Linköping during 2012. The second case was a musical named "Traces" that was set up by pupils at the local "Gimo secondary school" in the planned host municipality for the spent nuclear fuel final repository, Östhammar. The musical was based on their own thoughts, reactions and feelings about nuclear power, nuclear waste and the final repository conveyed and discussed within the group and with their teachers. 12 pupils and 3 teachers from the esthetical programme participated. They wrote the texts and composed the music together. 7 performances were then made in the end of 2013 for their own secondary school, for elementary schools and for the public in Östhammar and other neighbouring municipalities.

The main experience and the greatest value of the above described school and drama projects is so far that they positively showed to contribute to reach, involve and engage new groups of people in the field of nuclear waste disposal including the topics of memory keeping and how to communicate with future societies. Similar effects are also achieved and expected by the archaeology and language research projects related above. Frequent participation with presentations in conferences and seminars as well as frequent writing of articles in scientific papers has proved to be a successful way of increasing knowledge about the topic and putting it on a wider agenda than the nuclear waste agenda. One aspect, partly connected to this, that might be of interest to look further into would be a search for possible rituals around successive knowledge or information transfer that could support memory keeping to survive over time.



## CONCLUSIONS

To avoid inadvertent human intrusion in final repositories and disposal facilities and to give future societies the ability to make their own well informed decisions about the spent nuclear fuel and waste should continue to be the main target.

Time schedules for establishment, operation and closure of final disposal facilities vary quite a lot between different countries and waste management programmes. In some cases closure is planned within a few decades while in others no decisions about final disposal are yet taken or on the agenda.

Strategies and principles to meet the different time schedules and perspectives can preferably be identified and developed in international cooperation. A framework of basic principles, guidelines and a plan for redundancy of archives as well as continued exchange of ideas, experiences and good examples would be appropriate and useful in the short term. The first phase of the OECD NEA project on preservation of “Records Knowledge and Memory” (RK&M) will be concluded in 2014. It has showed to be a good and so far very successful platform for further international cooperation on the topic. We find it really essential that the proposed continuation will be strongly supported by the members to get the necessary approval. Proper measures and solutions can, should, and will then be found, developed and decided in due time by each country and waste management programme before the end of operation and closure of repository facilities. Quick fixes, simple solutions or shortcuts shouldn't be expected, required or promoted in early stages, many decades or even hundreds of years in advance. That wouldn't be appropriate nor necessary considering safety requirements and time perspectives.

A vital part of the work on preservation of information and communication with future generations in the short term, in addition to continuous documentation and archiving, is to spread information about the topic to as many humans, groups of people and fields of science and business as possible. This in order to widen the platform for dialogue by reaching, involving and engaging new groups and individuals making them take part and actively contribute to identifying and further developing proper solutions until the time for future closure of the necessary final disposal facilities.

Possibilities to involve locals and the host municipality without inducing new or further responsibilities on them ought to be investigated more thoroughly. Measures of interest for further studies in this field might be such as local archives and museums, design and maintenance of markers and monuments, continuously returning school and education topics, monitoring and other possible events or rituals for transfer of knowledge and memory keeping.

## REFERENCES

1. M. JENSEN, *Conservation and retrieval of information: elements of a strategy to inform future societies about nuclear waste repositories: final report of the Nordic Nuclear Safety Research project KAN-1.3*, Nordic Nuclear Safety Research, Stockholm; Sweden (1993).
2. M. JENSEN, *Informing future societies about nuclear waste repositories*, Radwaste Magazine, April 1994, v. 1(2), p. 51-61.

3. T. ENG, *The value and need for long term conservation of information regarding nuclear waste repositories - High level radioactive waste and spent fuel management*, proceedings of the 1993 International Conference on Nuclear Waste Management and Environmental Remediation, Prague, 1993, v. 2, p. 711-714.
4. T. ENG, E. NORBERG, J. TORBACKE et. al., *Information, conservation and retrieval*, SKB Technical Report 96-18. SKB, Stockholm, Sweden (1996).
5. M. BOWEN-SHIRE, H. JANDER and K. WANIEWSKA (Vattenfall Power Consultants), *Kunskapsbevarande för framtiden – fas 1 (only available in Swedish, title translation "Knowledge preservation for the future – phase 1")*, SKB Report P-07-220, Stockholm, Sweden (2007).
6. M. BOWEN-SHIRE, D. ECKERHALL, H. JANDER and K. WANIEWSKA (Vattenfall Power Consultants), *Bevarande av information om slutförvar för använt kärnbränsle – förslag till handlingsplan (only available in Swedish, title translation "Preservation of information about a final repository for spent nuclear fuel – proposal for an action plan")*, SKB Report P-08-76, Stockholm, Sweden (2008).
7. OECD NEA Radioactive Waste Management Committee, *Vision for the RWMC Project on "Preservation of RK&M across generations"*, NEA/RWM(2011)6/REV2, Paris, France (2011).
8. G. BANDOLIN (University College of Arts, Craft and Design Stockholm) and S. SÖRLIN (The Royal Institute of Technology Stockholm, School of Architecture), *Laddade landskap – värdering och gestaltning av teknologiskt sublimes landskap (only available in Swedish, title translation "Loaded landscapes – evaluation and design of technologically sublime landscapes)*, SKB Report R-07-14, Stockholm, Sweden (2007).

## ACKNOWLEDGMENTS

The following persons get my well deserved acknowledgements for direct or indirect contributions and inspiration both when writing and compiling this paper and continuing our work on the topic in general:

- Saida Laârouchi Engström SKB, Patrick Charton ANDRA and Claudio Pescatore OECD NEA for understanding the importance of the topic and promoting current and further work.
- Sofie Tunbrant and Mikael Gontier, current SKB colleagues also working on the topic.
- Anastasia Pettersson, SKB's archiving expert.
- Cornelius Holtorf, Anders Högberg and Ola Wikander, scientists from The Linnaeus and Lund Universities for great engagement and input from other fields of work and perspectives.
- Torsten Eng and Per Olov Lindberg, former SKB employees behind SKB's early efforts within the field starting in the 1990's.
- Michael Jensen, senior expert at Vattenfall and former employee of The Swedish Radiation Institute and the regulator SSM, deeply involved in the topic from the beginning.



