Knowledge Preservation for Nuclear Waste Repositories

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Study supported by

Wiener Umweltanwaltschaft / Vienna Ombuds Office
for Environmental Protection

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Thanks to Tahrin Alam, who supported research during her internship at the Austrian Institute of Ecology.

Vienna, 2018

Content

Summary

Spent fuel and other high radioactive nuclear waste have to be isolated from the environment for one million years or longer– an unimaginable long period. We do not even know if the human species will exist that long.

Irrespective of our position pro or contra nuclear energy use, nuclear waste is a problem that all of us have to deal with. In a first step it would be helpful if no more nuclear waste is produced until a safe solution for long-term disposal has been found.

The nuclear waste Directive 2011/70/EURATOM Art. 12 (1) (e) defines that EU countries have to include concepts in their waste management programmes how to ensure safety of their repositories also after end of operation. But until now, neither a convincing concept exists to prevent radioactive substances from leaking out of a repository, nor a concept to preserve all necessary knowledge on nuclear waste and future repositories hidden in a geological barrier, and how to inform future generations to handle a possible leakage.

In this project, existing ideas for knowledge preservation were researched and assessed. A workshop on 11 April 2018 in Prague was used to discuss with interested NGOs and members of the public and to develop argumentations for participation procedures for future deep geological repositories.

1 Introduction: One million years into the future

Radioactive waste results from energy production, military use, reprocessing of spent fuel, research, industry, medicine, from uranium mining and fuel production. Especially spent fuel and transuranic waste from nuclear weapons have to be stored for about one million years or longer, an unimaginable long time period.

Radioactive waste has to be isolated from the environment until the radioactive nuclides have decayed to a level that can be considered as safe. In today's legislation this corresponds to the clearance levels for each nuclide according to radiation protection law. In the EU, these levels are defined in Council Directive 2013/59/EURATOM and in national legislations.

Radioactive decay is characterized by half-life. Half-life is the time period in which half of the radioactivity has decayed. For example: Cesium-137 has a half-life of about 30 years, Plutonium-239 of 24,000 years, Iodine-129 of 15.7 Million years. All three nuclides and a lot more are present in high level nuclear waste.

In brief: What happened in the last five million years, what is expected in the next?

This is a difficult question. A look in the past may help to get a feeling for dimensions.

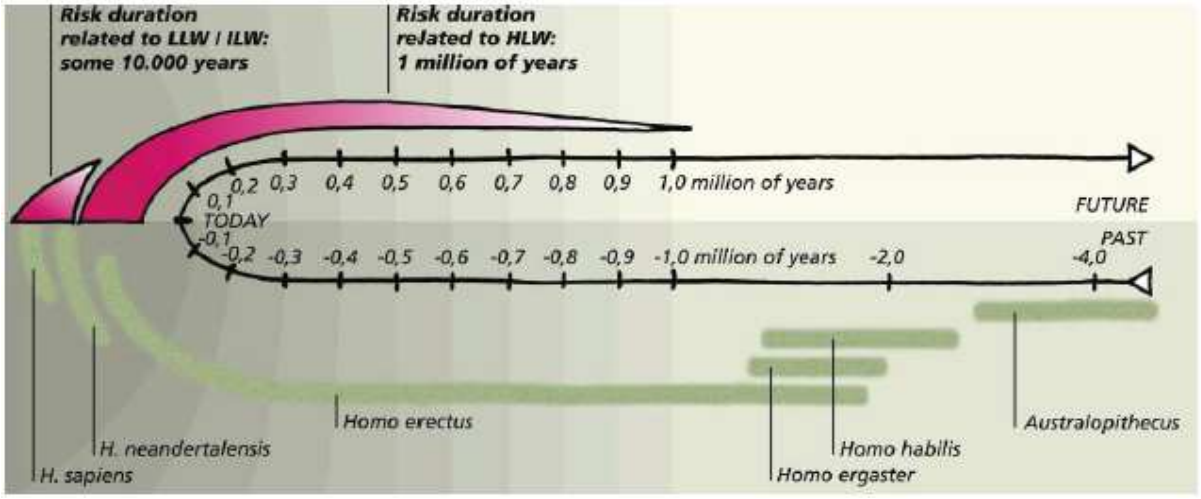

Figure 1: Timescale of hominide evolution (NEA-OECD 2013, p. 18)

One million years ago, the mayor continental drift was long over, continents were separated as we know them today.

Homo erectus has developed in Africa about 1.8 Mio years ago, and has become extinct after more than 1 Mio years, followed by other hominid species.

18,000 years ago the northern continents have been covered in thick ice.

The next ice age could start in about 15,000 years (or a bit later due to climate change).

Artificial intelligence could be a driving force for human development – in whatever direction.

In the next one million years continental drift will be overall very small, but geological shifts are possible, also mega-volcanic activities or meteorites crashing down on earth are imaginable.

By the end of the next five million years humans and many animal and plant species could possibly have become extinct, except those species which were able to adapt to new living conditions. For non-human species the evolution will go on anyway.

Steven Hawkings informed us two years ago that humans will become extinct even earlier, in 1,000 years, due to climate change, nuclear war and pandemics[1]. In this case we would only have to think about protecting other species than humans from our nuclear waste.

Figure 2: How the world could look like during the next ice age (Dixon and Adams 2016)

[1] https://www.welt.de/kmpkt/article159590391/Menschheit-hat-noch-1000-Jahre-bis-sie-ausstirbt.html

2 National nuclear waste management programmes in EU member states: concepts for the time period after closure of the final repositories?

According to **Council Directive 2011/70/EURATOM** „establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste“ (Nuclear Waste Directive), the EU Member States are obliged to prepare **national programmes on the management of spent fuel and radioactive waste** and notify them to the European Commission (Art. 13). The programmes need to include all waste management steps. Goal is the safe and responsible management to protect workers and the general public against the dangers arising from ionizing radiation. Any undue burden on future generations should be avoided, also in the post-closure period of repositories as is specified in Article 12 of the Nuclear Waste Directive:

Article 12: Contents of national programmes:

1. The national programmes shall set out how the Member States intend to implement their national policies referred to in Article 4 for the responsible and safe management of spent fuel and radioactive waste to secure the aims of this Directive, and shall include all of the following:

(e) the 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;

Member States had to notify their nuclear waste management programmes to the European Commission for the first time in August 2015. Now, in May 2018, there are still some programmes missing. Furthermore, in the notified programmes Member States did not deal with this question satisfactorily. The European Commission made an overview and assessment of the national programmes in 2017 and concluded:

"Of the Member States with nuclear programmes, only a few have presented detailed post-closure plans mainly for near-surface disposal facilities[2] *while* ***post-closure measures for deep geological facilities are either not foreseen or not addressed****.* ***Information on the Member States' approach towards preservation of knowledge after the closure of disposal facilities is limited in most of the national programmes.*** *This is an area that Member States should develop further in their national programmes."* (EC Report 2017, p. 12)

One of the countries discussing memory preservation in its national programme is **France**. The French National Radioactive Waste Agency ANDRA's long-term memory-preservation project will be discussed in this study in chapter 3.3.

Like France**, Sweden** is quite active in developing concepts for knowledge preservation. SKB, the Swedish Nuclear Fuel and Waste Management Company, and also the Riksarkivet are involved in the OECD-NEA project RK&M (see chapter 3.4). SKB is one of the funding participants of this project. Two archaeologists from the Linnaeus University are cooperating with SKB since 2012 in interdisciplinary research projects on radioactive waste. (Holtorf and Högberg 2016)

[2] Period for active and/or passive control after closure of a near-surface disposal facility are either not foreseen at all or range from 30 to 300 years.

3 Ideas and concepts for solving the question of knowledge preservation for nuclear waste repositories

Research on the knowledge preservation started in the 1980ies in parallel in the US with the Human Interference Task Force and in Germany with the birth of nuclear semiotics. But after the 1980ies not much research was conducted until a revival in 2010 with ANDRA's activities in France and the international NEA-OECD project RK&M in 2011. In between an alternative concept of "Rolling Stewardship" evolved which did not enter mainstream research but nevertheless is important.

The following activities will be discussed in this study.

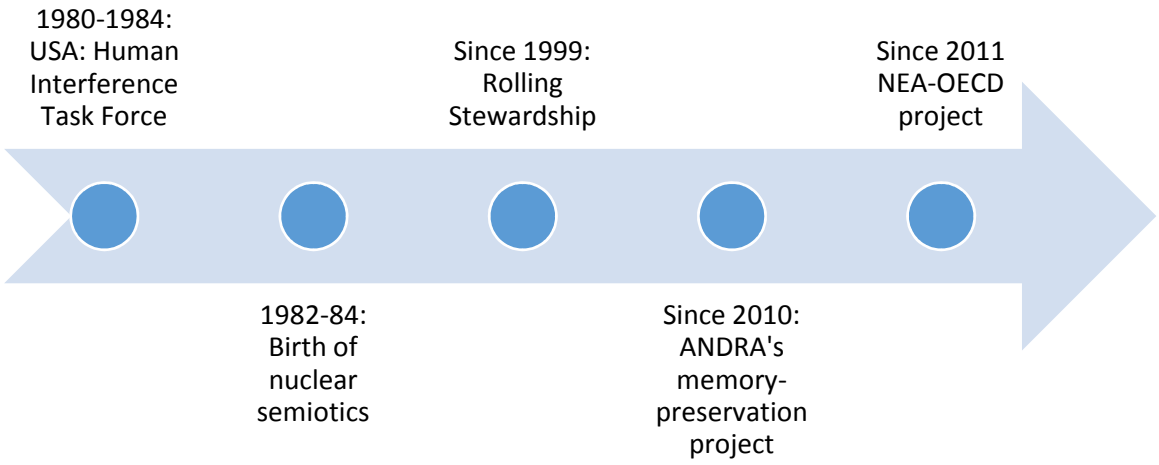

Figure 3: Timeline of main brainstorming and research activities for knowledge preservation

3.1 The Human Interference Task Force (HITF) and the Waste Isolation Pilot Plant (WIPP)

The US Department of Energy created the so-called **Human Interference Task Force (HITF)** in 1980 with the aim of developing a method to warn future generations for up to 10,000 years to not intrude in a nuclear waste site. In 1984, HITF published its results in a technical report (HITF 1984).

In this report, the authors expressed their trust in a very high likelihood of successful waste isolation and protection of humans by siting and technological factors (HITF 1984, p. 2ff.) On the other hand, the possibility of interference by humans was seen as dominant contributor to the post-closure risk. A high risk was seen by direct interference like drilling a borehole directly into the sealed repository, e.g. in the search of valuable mineral resources.

> A surprisingly result is the probability of a borehole piercing into the repository in the next 10,000 years given by US Environmental Protection Agency EPA: Based on historical drilling rates in the region of the WIPP, 67.3 boreholes per square kilometre over the 10,000 year period are predicted. But due to recent increases in drilling in the region even 148 boreholes per square kilometre can be expected. (Tracy et al. 2016)

The risks of war or terrorism were also included in the HITF assessment, resulting in the recommendation that "[r]epositories should, therefore, be unattractive targets for war, sabotage, or terrorism." (HITF 1984, p. 3) With the terrorism experiences of today, this recommendation sounds very outdated.

Interesting is also one of the premises of the HITF-project: *"…although this generation bears the responsibility for protecting future societies from the waste that it creates, future societies must assume the responsibility for any risks which arise from deliberate and informed acts which they choose to perform"* (DOE 1980, p. II-189) Which is to say that the responsibility for future (unintended?) intrusions in sealed repositories lies within future generations?

The HITF defined a time period of 10,000 years after closure of the repository as adequate for transmitting information. After that time, the hazard of the radionuclides should have decreased due to decay. But also the consideration of natural phenomena like the prognosis for climate change were seen as too uncertain in a longer time period.

Research results were produced for the following five topics

- Siting
- Repository design
- Communications: Message durability, detectability, comprehension, multiplicity
- System effectiveness
- Applicability

One suggestion of the HITF was to build a marker in form of an obelisk with several different levels of warning messages. These marker obelisks were planned to be arranged around the disposal site.

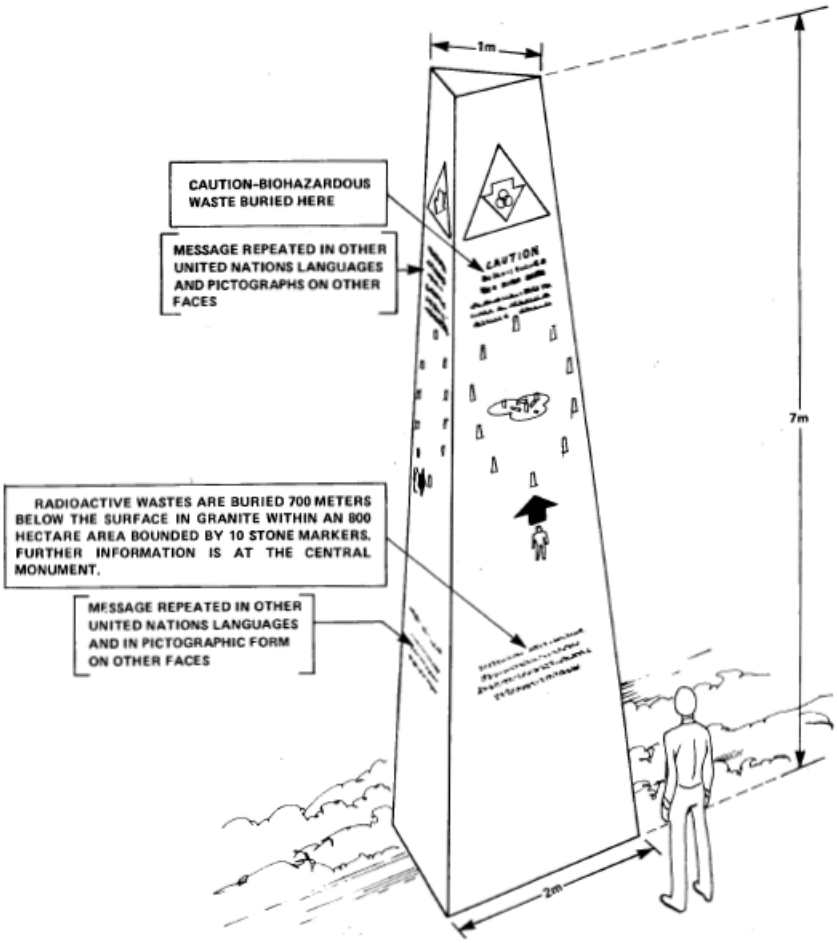

FIGURE 7-2. PERIPHERAL MARKER MESSAGE

Figure 4: Marker obelisk of 7 m heights with several warning messages (HITF 1984, p. 80)

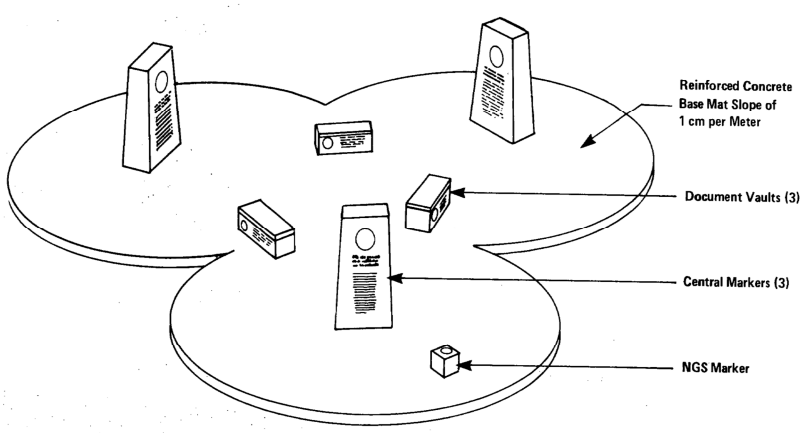

FIGURE 7-3. CENTRAL MONUMENT

Figure 5: Central monument consisting of marker obelisks with warning messages (HITF 1984, p. 81)

In **1993 the concepts of the HITF were updated for use in Waste Isolation Pilot Plant (WIPP).** The WIPP is located in New Mexico. It is a repository in a salt bed for military transuranic waste like Plutonium. For updating the first ideas of HITF two teams worked in parallel on the development of a concrete concept for warning and informing future generations of WIPP, resulting in these basic principles:

"The expert panel identified basic principles to guide current and future marker development efforts: (1) the site must be marked, (2) message(s) must be truthful and informative, (3) multiple components within a marker system, (4) multiple means of communication (e.g., language, pictographs, scientific diagrams), (5) multiple levels of complexity within individual messages on individual marker system elements, (6) use of materials with little recycle value, and (7) international effort to maintain knowledge of the locations and contents of nuclear waste repositories." (Trauth et al. 1993, p. i)

Their work resulted in development of warning messages including not only writing, but also faces and drawings of humans; and the development of landscape markers like spikes aimed at scaring people.

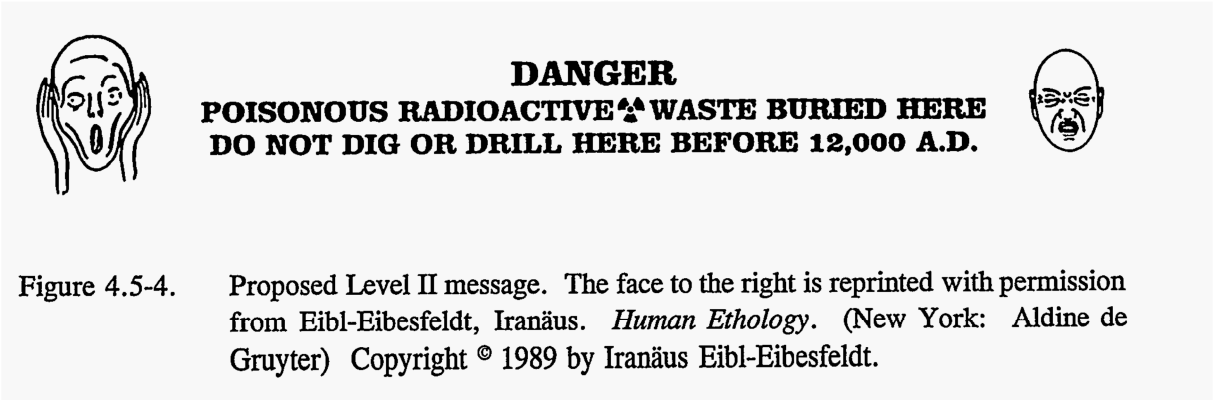

Figure 4.5-4. Proposed Level II message. The face to the right is reprinted with permission from Eibl-Eibesfeldt, Iranäus. *Human Ethology*. (New York: Aldine de Gruyter) Copyright © 1989 by Iranäus Eibl-Eibesfeldt.

Figure 6: Faces and written warning message (Trauth et al. 1993, Report Team A, p. F-13)

This figure shows the proposal for a warning including human faces, the left face showing horror in the style of Edvard Munch's "The Scream", and the right face meaning to show sickness or nausea. The written message in the middle should be written in several different languages, leaving also a blank to encourage people to translate the message into up-to-date language if necessary. (Trauth et al 1993, p. F13)

The next figure shows a result of Team B who developed warning messages in form of a story.

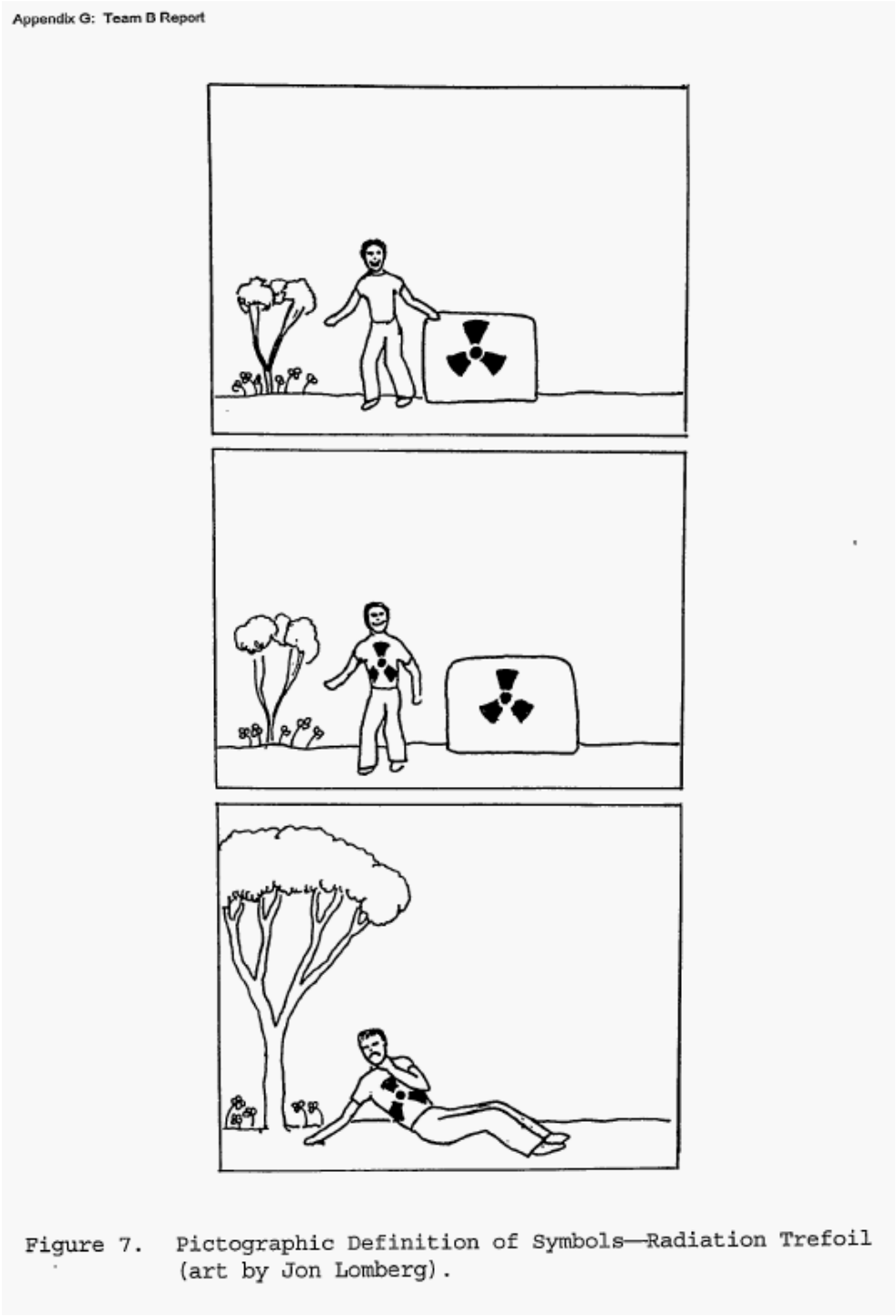

Figure 7: Warning as a pictogramm history (Trauth et al. 1993, Report Team B, p. G-20)

Such a story would assume that future readers recognise the chronological order of the pictures in the intended way.

Moreover, it is interesting that only white male faces or figures in a certain age group are used. A modern version of these warning would have to acknowledge the global diversity systematically.

The two research teams also made a lot of proposals for monuments and earth works which should mark the landscape to prevent people from intrusion. Here are some impressions of the work.

Figure 8: Michael Brill & Safdar Abidi: Landscape of Thorns. http://pictify.saatchigallery.com/1147839/michael-brill-safdar-abidi-landscape-of-thorns

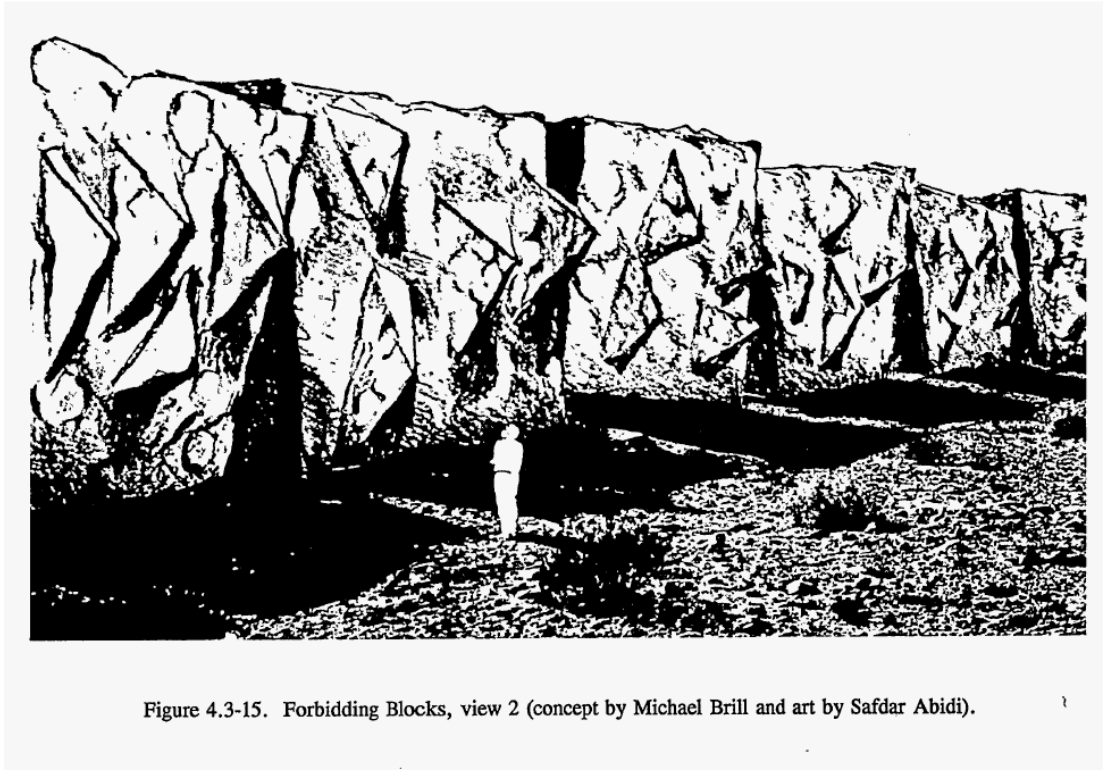

Figure 4.3-15. Forbidding Blocks, view 2 (concept by Michael Brill and art by Safdar Abidi).

Figure 9: Forbidding blocks, view 2 (Trauth et al. 1993, p. F-75)

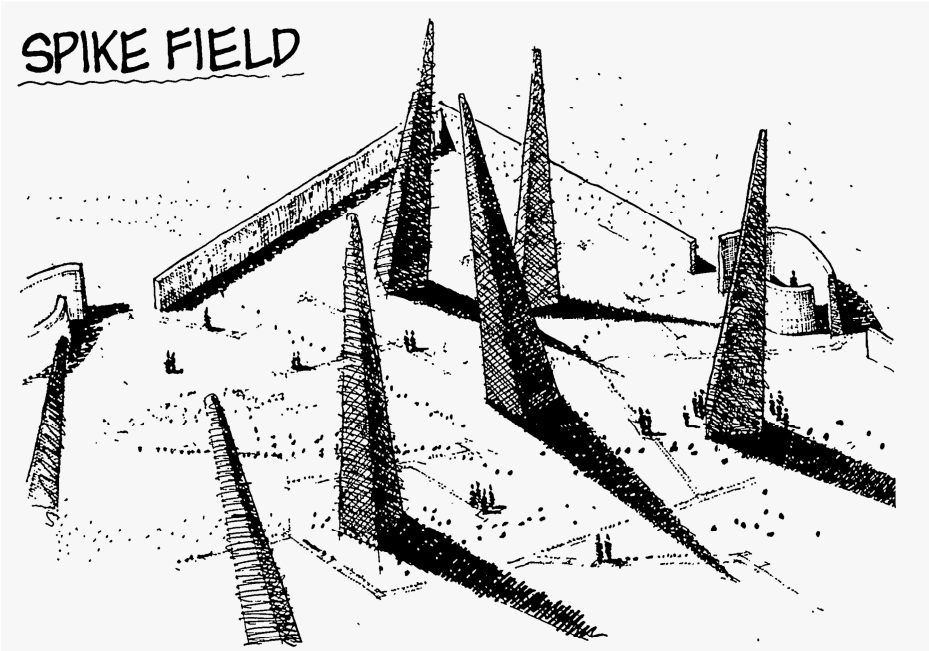

Figure 4.3-3. Spike Field, view 1 (concept and art by Michael Brill).

Figure 10: Spike field (Trauth et al. 1993, p. F-63)

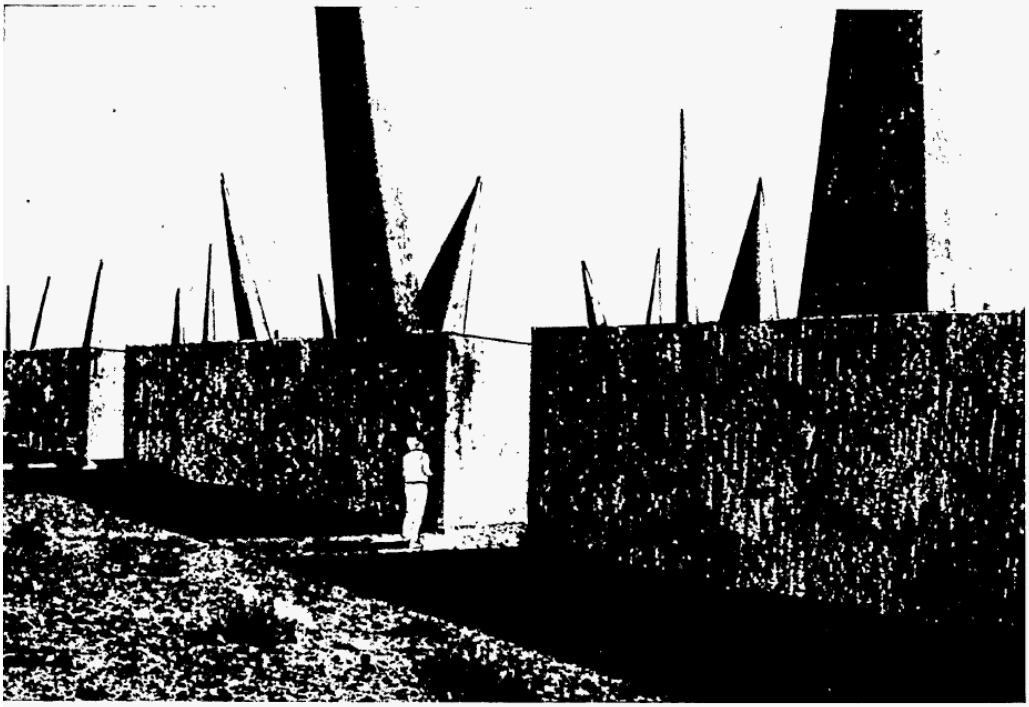

Figure 4.3-4. Spike Field, view 2 (concept by Michael Brill and art by Safdar Abidi).

Figure 11: Spike field, view 2 (Trauth et al. 1993, p. F-63)

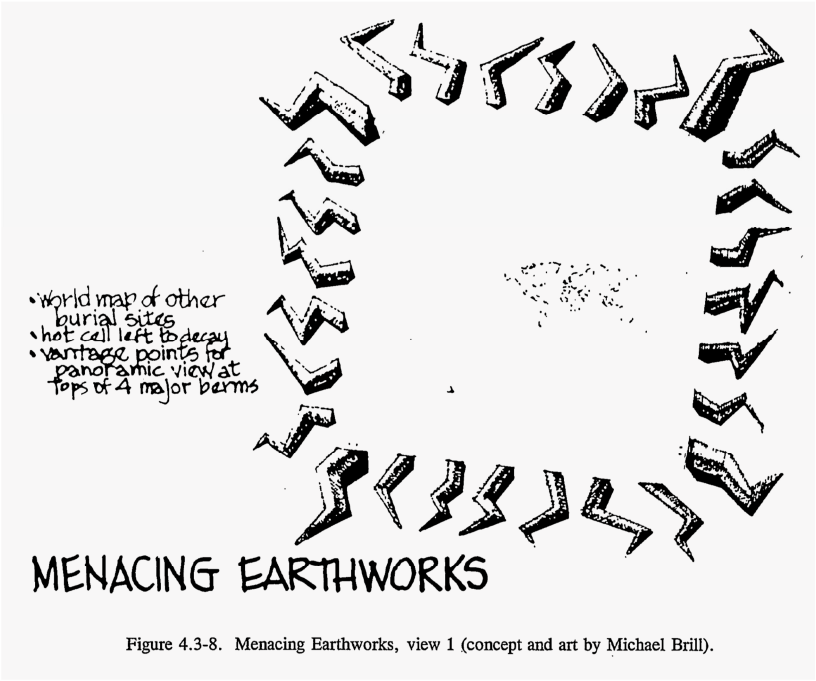

Figure 4.3-8. Menacing Earthworks, view 1 (concept and art by Michael Brill).

Figure 12: Menacing earthworks (Trauth et al. 1993, p. F-68)

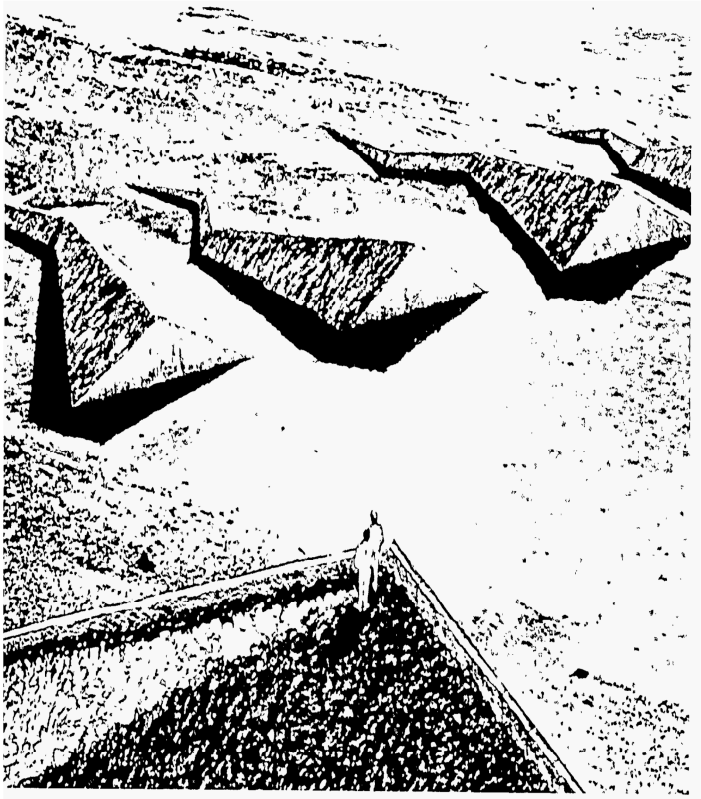

Figure 4.3-9. Menacing Earthworks, view 2 (concept by Michael Brill and art by Safdar Abidi).

Figure 13: Menacing earthworks, view 2 (Trauth et al. 1993, p. F-69)

In 2004, the **Permanent Markers Implementation Plan** for the WIPP was developed. (US DOE WIPP (2004) EPA approved a permanent marker system of 32 monoliths with 7m height that will secure the site with an information centre in the middle which is surrounded by 16 more monoliths. More warning markers are buried at the site.

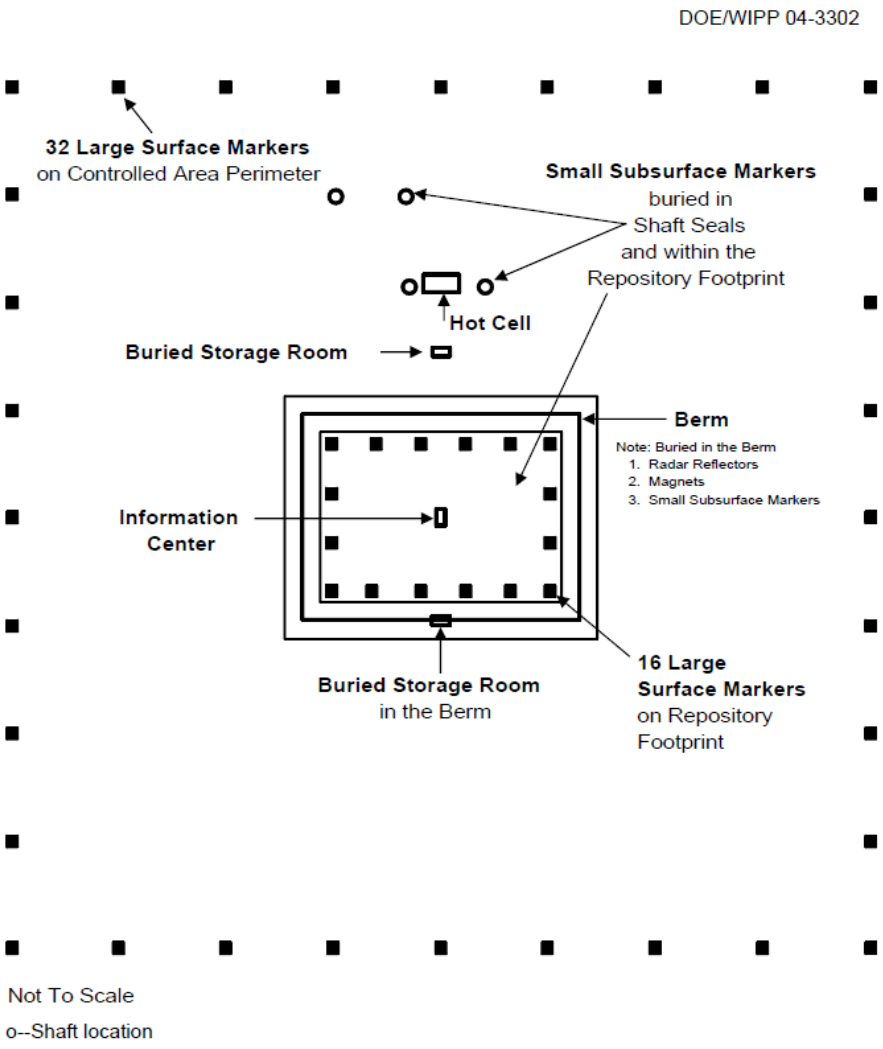

Figure 2. Permanent Markers Components

Figure 14: Permanent Markers Plan for WIPP

In 2014, an accident occurred at WIPP (the so-called cat-litter accident[3]). The re-opening of the plant is envisaged for 2021. The WIPP was planned to be closed in the early 2030ies, which was postponed to 2050. For the first 100 years after closure the WIPP is mandated by law to institute active controls meaning fences, gates, and armed guards on patrol. But the once approved Permanent Markers Implementation Plan is now being evaluated. (Strothard 2016) The concept of huge and expensive markers seems to be outdated already: *"Building markers and monuments that are out of proportion to the risk being presented to the future is not in keeping with generational equity."* (Patterson et al. 2013)

[3] https://www.energy.gov/em/downloads/technical-assessment-team-report

3.2 Nuclear semiotics

Semiotics is defined as study of meaning-making, the study of sign process (semiosis) and meaningful communication. Widely known is a book of Roland Posner from 1990 with the title "Warnungen an die ferne Zukunft. Atommüll als Kommunikationsproblem[4]." Posner's book is based on a questionnaire that was sent to twelve semiotics scientist "from East and West" between 1982-1983. The question was: "How is it possible to inform our descendants in the next 10,000 years about the sites and specific dangers of nuclear waste?" The answers were published first in the Journal of Semiotics, Vol 6, No. 3 1984.

What are the proposed solutions? Amongst others:

- Artificial moon and data archive in the cellar as the safest data storage options
- Securing data by randomizing code against unauthorized persons
- Genetics: mathematical code on biological matter due to the assumption that only biology continues, but not culture
- Genetically manipulated cats shall change their skin colour when getting in contact with radioactivity. The exact site of the waste disposal can be kept secret with this solution.
- Warning signs should be renewed due to changes in language, and the reformulated warning messages should be located concentrically around the site
- Dissemination of myths, fairy tales and legends
- A nuclear priesthood (Thomas Seboek) shall be established and artificially created rituals and legends shall be renewed from time to time and passed on between the generations of the priest
- Establishing a chamber in national states for future affairs

None of these ideas has been developed further for use in practise until now.

A chapter of the book is written by a gender expert, Susanne Hausner. She asks an important question: Is it responsible to let the people find solutions that have caused the problem? (Hausner in Posner 2007, p. 13) This leads to the question who is and who should be responsible, and especially who is even capable to act responsible in the long-term.

[4] Warnings to the far future. Nuclear waste as communication problem.

3.3 France: ANDRA's long-term memory-preservation project

ANDRA is the French National Radioactive Waste Agency. And it is nearly the only nuclear waste authority in Europe that engages in research for knowledge preservation. The start of the project was in 2010, and since then about 20 part-time employees are working on it.

In this project, ANDRA prepares for two activities:

1. the memory-preservation over up to 1,000 years for its existing disposals CSM (Centre de la Manche[5]) and CSFMA (LILW disposal in Aube)
2. the multi-millennial scale memory-preservation for the future disposal for spent fuel and high level waste

The chosen measures are the same for all types of facilities, but for the multi-millennial scale additional measures are planned. This memory-preservation system contains active and passive memory mechanisms:

- Passive records of all data of the disposals are stored as detailed memory at two sites, and as summary memory. Records are also printed on permanent paper[6] which is seen as the only durable medium for record keeping over the centuries. Records are updated every five years as long as the period of oversight will last. Also the piece of land on which the disposal is built, is being restricted from other use by legal means like land-use-plans.
- Active records are based on communication with the public, esp. with local information committees (CLI). It is believed that this system will last several centuries.

For the long-term preservation Patrick Charton and his team from the ANDRA's memory project developed a sapphire disc on which 40,000 pages of text and pictures can be stored. The content can be read with the help of a microscope. While the disc material as such should withstand one million years it nevertheless can be broken with a hammer, as Charton said at a conference[7]. And it is of course not sure that future humans can read and understand the content.

By the concept of ANDRA it can be seen that even the memory keeping for low and intermediate level waste repositories is a huge effort that has to be planned and managed carefully and which still needs research to be done.

[5] CSM was in operation from 1969 until 1994. The inventory of the disposed radioactive waste is not clear due to former disposal practices. Therefore, also long-lived radionuclides could have been disposed of in there – which makes it necessary to monitor the disposal after closing for a minimum of 500 years. http://www.andra.fr/international/pages/en/menu21/waste-management/waste-management-strategies/low-and-intermediate-level-short-lived-waste-1617.html, issued July 1996, seen 28 March 2018.

[6] Permanent paper is a paper made from pure cellulose with slightly alkaline pH and high tear-resistance. (ANDRA Essentials Series: Disposal Facilities: Preserving a collective memory for future generations; www.andra.fr/international/download/andra-international-en/document/editions/299.pdf)

[7] https://www.theverge.com/2012/7/13/3157081/andra-sapphire-disc-data-million-years, seen 07 May 208

3.4 NEA-OECD project "Preservation of records, knowledge and memory across generations" (RK&M)

This multinational research project was conducted in its first phase from 2011-2014, the second phase started in 2014 and will be finished 2018.

Members of the second project phase are: ONDRAF/NIRAS (Belgium), SCK (Belgium), NWMO (Canada), SURAO (Czech Republic), STUK (Finland), ANDRA (France), BfS (Germany), GRS (Germany), KIT (Germany), PURAM (Hungary), JAEA (Japan), RWMC (Japan), ENRESA (Spain), SKB (Sweden), Riksarkivet (Sweden), SSM (Sweden), NAGRA (Switzerland), SFOE (Switzerland), NDA-RWM (UK), US DOE (USA) and the IAEA.

Starting on the basis of a literature survey from the Swiss institute INA from 2010, several topics in the wide field of memory, knowledge and record preservation have been researched from a multi-disciplinary view.

The results of the first phase are (NEA-OECD 2015a):

The RK&M-project defined three timescales for knowledge preservation:

1. Short term: refers to the last period of operation, the time between emplacing waste has been finished and the repository is finally closed
2. Medium term: corresponds to the period of indirect oversight after final closure of a repository, up to 1,000 years
3. Long term: period with no oversight, beyond the medium term

National instruments for the preservation on RK&M have been analysed, with the result that the long-term is not covered adequately; especially the question of transfer of responsibility after the oversight period (medium term) is not covered.

No single mechanism or technique alone can preserve RK&M. A systemic approach including mediated and non-mediated transmission of information is needed.

Phase 2:

A first international conference was conducted in 2014 in Verdun, France. (NEA-OECD 2015a) This conference had the aim to introduce important areas for RK&M preservation to the public. Artists were invited to participate.

The following topics were decided to be prioritized in the second work phase:

- Archives: experiences of national archives will be studied and it will be assessed how they can contribute to the RK&M preservation topic.
- Key information file: All authorities should submit their information according to the key information file, for which the project is going to develop a table of content. ANDRA's summary document can serve as example.
- Markers: national case studies of markers will be discussed in their cultural context.
- International mechanism will be reviewed, including transfer of responsibilities.

At the conference, no participants from Africa, South America and large parts of Asia took part. This was reflected critically in one of the discussion groups.

On the website the following outputs are available:

- A glossary
- A study on markers reflecting the intergenerational warnings in the form of Japanese Tsunami Stones (NEA-OECD 2014a): Even if a warning system was available and understood by the population, the warning itself was largely ignored: Visible markers contribute to keeping memory alive, but memory does not guarantee safety or even consideration of the actions according to the warning.
- A study on international examples of loss of information, records, knowledge and memory for conventional waste disposal (NEA-OECD 2014b)
- A study on technical and societal aspects of monitoring of geological disposal facilities (NEA-OECD 2014c)
- A study on international mechanisms (NEA-OECD 2015b)

In a Collective Statement from 2014 seven guiding principles for RK&M preservation were defined (NEA-OECD 2014d), among them:

- Planning for the knowledge preservation should start while designing waste management plans (= now!) when funding is available
- Agreements with societal institutions and international bodies should be reached that are likely to survive beyond the closure of the repositories and end of operation of nuclear waste institutions

In the project studies and guiding principles, no definite solutions are proposed. The last workshop of the project has been held in Feb/March 2018, a final report will be the outcome. (NEA Monthly News Bulletin March 2018)

3.5 Concept of Rolling Stewardship

Rolling Stewardship can be translated as ongoing responsibility to care over generations. Each generation passes on the knowledge and the resources to the next generation.

While this concept was first mentioned by US National Research Council in 1995, it was further developed in 1999 by the US National Environmental Policy Institute for preparing future generations for long-term environmental clean-ups of waste sites that cannot be cleaned completely and have to be monitored and cared about over generations. (NEPI 1999) After that, it was adopted by the Canadian Coalition for Nuclear Responsibility CCNR for nuclear waste management. (CCNR without year)

CCNR defined nine points as important:

1. Humans can contain waste security for decades at a time (but not longer)
2. There is no solution to the waste problem right now – perhaps there will be in future
3. Therefore the nuclear waste should be continuously monitored
4. Retrieval is anticipated and actively planned for
5. Periodic repackaging is an integral part of the process
6. If leakage occurs timely corrective action will be taken
7. Rolling Stewardship is based on persistence of memory
8. Information can easily be transmitted to the next generation
9. Ongoing reminder that the problem remains to be solved

Every 20 years a review cycle shall be conducted to control the nuclear waste and if needed to re-package it. Also instructions shall be renewed in the cycle. This should endure as long as a permanent, safe solution has been found. The transmission of responsibility from one generation to the next could be conducted as a ceremony.

An organisation is needed to fulfil this task. The organisation should be independent from waste producers.

The Rolling Stewardship concept is in direct contradiction to the concept of abandonment (burying the nuclear waste in a geological repository and putting the surface back to green earth with the intention to forget about the repository). It is an alternative to manage the radioactive waste until a safe solution has been developed.

Especially interesting is the presumption that every generation passes not only information but also responsibility to the next generation. How this rolling stewardship can be accomplished in detail has to be researched, nevertheless, it seems to be a realistic way to tackle the problem for the time being. Organisations could and should work together with members of civil society to spread the knowledge as wide as possible.

3.6 A thought experiment: Open Care Project

The Inheritance project "Open Care" by Erich Berger and Mari Keto is an art project intended to be a thought experiment.

"OPEN CARE is a set of artefacts which propose a social thought experiment: what if nuclear waste were a very personal responsibility and thus part of our everyday life and our cities? It is an imaginary system for distributed nuclear waste storage which implicates us intimately in a much longer swathe of the future than most of us can imagine easily. The waste is encapsulated in steel pellets mounted in a bronze disk. An electroscope, gold leaf, an electrostatic rod and fur to charge it are provided along with instructions to check the level of radioactivity periodically, from generation to generation, to ascertain whether the waste of which you are custodian has become safe 'or if you and your descendants need to continue to care about it.' Rendering the huge timescale of radioactive decay into more meaningful units of lifetimes opens the question of collective care from a fresh perspective."[8]

In the figure the nuclear waste container is on the left shelf, housing 95 pellets of Americium-241. Several accessories needed for measuring are placed on the middle shelf and on the bottom of the show case, and an electroscope on the right shelf. The instruction manual is also part of the installation. If instructions are no longer understandable they shall be renewed during caring. On the wall to the right an autoradiograph can be seen, the result of a measurement.

[8] http://inheritance-project.net/index.php/page-3/

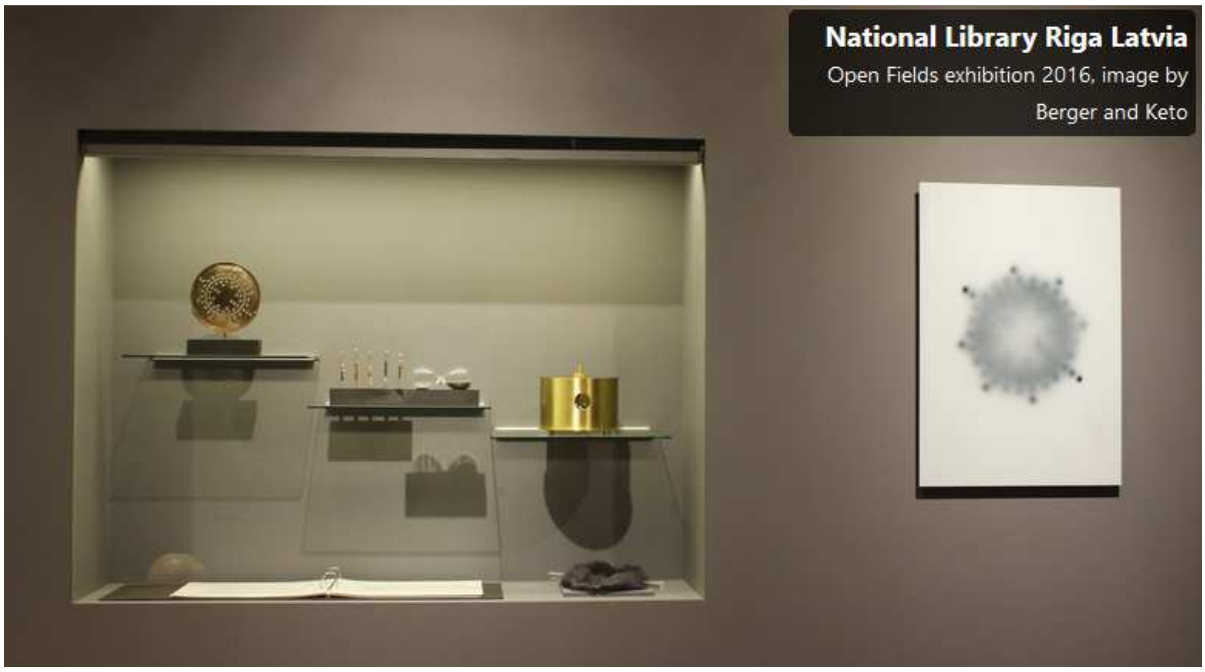

Figure 15: Inheritance project "OPEN CARE" by Erich Berger and Mari Keto, http://inheritance-project.net/index.php/page-3/

It is a bit spooky to think about personal responsibility to care for your personal portion of nuclear waste. But it is indeed an interesting thought experiment: What will happen when nuclear authorities and national states have ceased to exist? Who will be responsible in the end? How many people are able to take this responsibility if they are not used to care for the waste?

4 Conclusions and arguments for NGO's work

When summarizing the above presented ideas and concepts, the following points stand out:

- Research has started in the 1980ies, but until now there has not been much effort to advance it.
- Older research especially from USA is lacking adaption to modern knowledge on diversity of society. Not only language changes over time and has to be adapted in regular intervals. Warning methods have to be developed and tested on a global level. If images are used in warning messages they have to reflect the diversity of humans all over the world.
- Only a few countries engage in research on knowledge preservation. The other countries neglect the topic altogether.
- First projects have started for knowledge keeping over a period of a few hundred years. But until now no solutions for the long-term knowledge keeping have been developed that are ready for testing.
- Research seems to be concentrating on technological features and written communication. Cooperation with actual humans from civil society are mentioned as important, but models for such cooperation are still missing.
- The question of responsibility is not discussed in adequate detail. A situation where nuclear authorities and states have ceased to exist is possible, or even probable, which leaves civil society to take responsibility in the long term. And civil society is not prepared to do so.
- Civil society has not been participating in research on knowledge preservation until now to the extent that would be necessary.
- The idea of Rolling Stewardship is outstanding in the previous discussions. It provides the possibility to establish a safe and responsible management of nuclear waste until a final solution has been developed to dispose the waste safely. But even if this will not happen, the Rolling Stewardship idea can be developed for long-term care. But this idea also needs more research to be ready for use.
- The contribution of artists is valuable due to opening up windows for reflecting the difficult and unpleasant questions of responsibility of our generation.

It is obvious that more research has to be done. And it is also obvious that civil society has to take a more active part in this research.

Considerations for a possible point of view for NGO's work

NGOs working on the topic of nuclear waste basically have two goals:

1. **that the production of nuclear waste is stopped as soon as possible; and**
2. **that the existing nuclear waste is stored and disposed in a way that our and future generations and the biosphere are safe from negative consequences.**

Even if the strategies to accomplish these goals may differ in some aspects, it is nevertheless necessary to deal with nuclear waste management now and not only in the future when the waste production has hopefully stopped. Because now is the time policy decisions are made on EU level and also in other countries, and it is essential that NGOs take part in these discussions to avoid errors that could be irreversible. The urgent need to start with the work now must not be mistaken as an urgent need to decide on the solution now or in the near future.

A technological and geological safe solution for a high level waste repository does not exist today. Perhaps it will exist in the future, perhaps not. Therefore, **retrievability of the nuclear waste has to be enabled for as long as no safe and absolutely satisfying solution exists**. The concept of total abandonment, meaning deep geological disposal without marking the site and trying to keep memory alive seems not to be the best solution at present. Nevertheless, long-term storage in interim storages for hundred years or more is not a safe option either, especially if the inventory increases and ageing effects can impact waste containers and the facilities which were not designed for such long time periods. Also the risk that radioactive substances are used for manufacturing nuclear weapons is rising if the old facilities are not designed to withstand intrusions.

NGOs are engaged in discussions on safety of technological and geological barriers for waste repositories. It is also necessary to **engage in research activities for preservation of knowledge** on nuclear waste and on repositories. As this study shows, there is not much research going on, and most countries in the EU do not even waste a thought on the time after the closures of their future repositories. This has to change. Without more effort in research the question how knowledge can be preserved on the long-term will not be solved. It is neither easier to solve nor less important than questions of technological and geological safety.

Research seems to be focused on the own national state or on the EU. But nuclear waste will accompany us for so long that it is very unlikely that over the relevant time period states or the EU will keep existing as we know it now. The same is true for nuclear authorities. Therefore the **question of responsibility** has to be asked: who will be responsible and capable for the long-term care of nuclear waste? Chances are good that civil society will be in charge someday. Therefore, civil society has to prepare itself for this challenge, starting now, and not only on a national but also on a **global level**. This preparation should be financed by the nuclear waste producers.

Participation procedures

In the EU Directive 2011/70/Euratom is in force, which had to be implemented into national law. In this Directive every EU member state has to make a national nuclear waste management programme that includes, amongst others, “the 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” (Art. 12 (1) e)

Every nuclear waste management programme should have been subjected to a **Strategic Environmental Assessment (SEA)** according to SEA Directive 2001/42/EC. Also if significant changes occur in the waste management programme, a new SEA has to be done.

Every facility for disposal of nuclear waste has to undergo an **Environmental Impact Assessment (EIA).** If there is an EIA for a repository, also the concepts for long-term knowledge preservation should be presented to the public.

Outside European Union, these participation procedures are based on the **ESPOO Convention**[9] and the **SEA Kyiv-Protocol**[10].

Besides these possibilities for participation, also on transboundary level, there will be always situations in an NGO s working life to ask questions and demand answers and concepts.

[9] https://www.unece.org/env/eia/eia.html

[10] https://www.unece.org/env/eia/sea_protocol.html

Questions of interest for participation procedures

- How will the knowledge on nuclear waste and on repositories be preserved on the long-term, especially
  - in nuclear authorities after the end of nuclear energy use?
  - in civil society?
  - on the global level?
- What research activities are undertaken to find a solution for knowledge preservation?
- How will the solutions for knowledge preservation be financed?
- Who will be responsible for knowledge preservation on nuclear waste?
- Which organisations/stakeholders are invited to participate in research on knowledge preservation on nuclear waste?
- How can NGOs and civil society participate in this research?
- Who decides on the methods that will be used for knowledge preservation?
- Is retrievability of nuclear waste foreseen in the country's waste strategy? For how long and how?
- Is the concept of Rolling Stewardship considered?

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