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NUCLEAR ENERGY AGENCY
RADIOACTIVE WASTE MANAGEMENT COMMITTEE

Preservation of Records, Knowledge and Memory Across Generations

Reference Bibliography within NEA RK&M Project

This bibliography aims at providing an overview over the work performed in the field of the preservation of records, knowledge and memory in relation with radioactive waste management, especially disposal. For each entry, an abstract outlining the relevance of the document to the topic of RK&M is provided. This bibliography is a living document that will be updated regularly during the lifetime of the RK&M project.

Please send any queries regarding this document to Claudio.pescatore@oecd.org

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NEA RK&M INITIATIVE

PRESERVATION OF RECORDS, KNOWLEDGE AND MEMORY ACROSS GENERATIONS - REFERENCE BIBLIOGRAPHY

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New additions since February 2014 Meeting in red

INTRODUCTION

This bibliography aims at providing an overview over the work performed in the field of the preservation of records, knowledge and memory in relation with radioactive waste management, especially disposal. For each entry, an abstract outlining the relevance of the document to the topic of RKM is provided.

The following criteria are currently used to select the references:

- The document (or at least part of it) addresses the preservation of RKM in connection with the management of radioactive waste
- The document is publicly available or can be made available upon request
- One synthesis document (such as a report) is preferable to a list of papers with a similar content.
- Original documents (scientific reports and papers) are preferred to reviews or press coverage.

The bibliography should help the participants in the project to identify the topics of concern in the field of RKM and, eventually, the issues that have not yet been addressed.
The current bibliography is not meant to be an all-encompassing list that includes any generic reference that might be useful in the study of those topics. Therefore it does **not** include:

- general studies outside RWM , e.g. on memory loss, communication, or the history of institutions
- studies belonging to the field of RWM but that are only indirectly related to RKM preservation[1].

Unless stated otherwise, all documents are available from the Nagra Library, either on paper or in electronic form.

[1] For instance, the bibliography would not include studies of climatic changes at a specific site. Clearly, they would be relevant for the development of a marking system at that site, but they could be used for many other uses as well.

BIBLIOGRAPHY

- Adams M.R., Kaplan M.F. (1986): *Marker development for Hanford Waste Site disposal.* – Waste Management '86: Waste isolation in the U.S. technical programs and public education: proceedings of the symposium on Waste Management at Tucson, March 2-6, 1986; 1: General interest, p. 425-432. http://www.wmsym.org/archives/1986/V1/72.pdf

  Certain radioactive wastes, including stored wastes in single-shell tanks and pre-1970 solid waste burial grounds and contaminated soil sites, are currently located at the Hanford Site. The Hanford Defence Waste-Environmental Impact Statement is being prepared to assess options for the disposal of these wastes. In particular, barrier and marker systems are being designed and developed for placement over the wastes following site preparation. Archaeological analogues have been examined to provide guidance for the design of markers intended to communicate for up to 10,000 years. Materials, dimensions, and messages have been specified for both surface and sub-surface prototype markers. A prototype surface marker has been designed, and its procurement is pending. The integration of the barrier design and markers into a system has also been planned. Plans for placement of both surface and sub-surface markers have been completed.

- Advisory Committee on Nuclear Safety, Canada (2001): *Research in Support of Operational Safety at Nuclear Power Plants*. INFO-0724. ACNS, Ottawa. http://nuclearsafety.gc.ca/pubs_catalogue/uploads/ACNS27_E.pdf

  This document was prepared by an advisory committee to the Canadian regulator in order to assess the potential safety-related consequences of a significant reduction in funding for nuclear power research and development (R&D) in Canada. The committee was asked to make recommendations regarding major safety areas that required continued R&D, regarding actions that might be taken to ensure that trained persons would be available for recruitment within the industry, and regarding succession planning for staff both in the industry at large and within the regulatory body. The focus was primarily on the nuclear electricity generation industry. The report supported recommendations that had been made within the industry for research needs, and recommended that a detailed assessment of R&D needs for safety be carried out. Special mention was made of emergency response capability as an area needing attention. The report also recommended an assessment of the retention of corporate memory in the nuclear industry, and contains a discussion of several types of knowledge that contribute to corporate memory, ranging from textbook scientific knowledge to information that is contained primarily in personal notes and recollections. The report recommended the establishment of a cooperative training program involving the industry, the regulator, research institutions and universities, with "appropriate emphasis" on ageing, decommissioning and abandonment issues. The report also recommended the formulation of a clear national policy on nuclear energy, and the separation of responsibility for funding of waste management from funding for research aimed at development of the nuclear generating industry.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2009) : Documents available on ANDRA's website :
  Se souvenir [To remember]:
  http://www.andra.fr/pages/fr/menu1/les-solutions-de-gestion/se-souvenir-19.html
  Le papier permanent [Permanent paper]:
  http://www.andra.fr/pages/fr/menu1/les-solutions-de-gestion/se-souvenir/le-papier-permanent-82.html
  L'expérience du passé [The experience of the past] :

http://www.andra.fr/pages/fr/menu1/les-solutions-de-gestion/se-souvenir/l-experience-du-passe-83.html

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2009): *Centre de stockage de la Manche : Rapport définitif de sûreté - Année 2009. Phase de surveillance. ["Centre de stockage de la Manche" facility (radioactive waste disposal facility, acronym CSM, located in the Manche district): Final Safety Report - 2009. Monitoring Phase]*. SUR.RP.ACSM.08.0017.A. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]
  The 2009 Safety Report represents the CSM final safety report. It was prepared to support the CSM's safety re-inspection (this installation is classified according to the Nuclear Safety Authority as Basic Nuclear Facility "INB no. 66") in its post-closure monitoring phase configuration. Accordingly, it takes stock of the lessons learnt from the initial years in this monitoring phase. It also takes into account all evolutions that have occurred in the regulations pertaining to nuclear facilities: Act n° 2006-686 dated June 13th, 2006 relative to transparency and safety in nuclear issues, and its application decree n° 2007-1557 dated November 2nd, 2007 relative to Basic Nuclear Facilities.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2008): *Centre de stockage de déchets radioactifs de la Manche (50), situé sur la commune de Diguelleville. Mémoire de synthèse pour les générations futures (destinée à maintenir une connaissance minimale aux générations prochaines et à toutes celles qui se succéderont jusqu'en 2500 au moins)*. ["Centre de stockage de la *Manche" facility (radioactive waste disposal facility – acronym CSM), located within the municipality of Diguelleville in the Manche district. Memory synthesis report for future generations (intended to retain minimal knowledge for upcoming and successive generations, at least up to the year 2500)*.]
  CSM Record DD.NSY.ADSQ.07.0017.A. ANDRA, Chatenay-Malabry.
  http://www.andra.fr/download/site-principal/document/CSM_memoire_de_synthese_pour_les_generations_futures.pdf
  A synthesis report intended for future generations and presenting a history of radioactivity, a history of the CSM and of its forecast impact on the environment, as well as the policy conducted by Andra in order to preserve a memory of the site. This synthesis report remains a draft one for now and it is expected that a final version will be completed at a later time.ANDRA, Chatenay-Malabry.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA), Charton P., Ouzounian G. (2008): A Challenge for Radioactive Waste Management: Memory Preservation. – *WM'08 Annual Waste Management Symposium: Proceedings*, February 24 -28, 2008, Phoenix, AZ.
  http://www.wmsym.org/archives/2008/pdfs/8014.pdf
  For short-lived waste for which disposal facilities have a life expectancy of a few centuries, ANDRA has set up a system for memory preservation. Based on the historical analysis on a comparable timescale and on an appraisal of information-conservation means, a series of regulatory as well as technical provisions were made in order to ensure that sound information can be transferred to future generations. Requirements associated to the provisions deal mostly with the legibility and formulation of the information that must be decrypted and understood – and therefore preserved – at least during the lifetime of the facilities. The paper describes the achievement at the *Centre de la Manche* Disposal Facility.
  In the case of deep geological repositories for long-lived radioactive waste, it is much more difficult to consider how to maintain the richness of the information over the long timescales. Both the nature and the form of the information to be transferred must be revised. It would be risky indeed to base memory preservation over the long term on similar mechanisms beyond 1,000 years. Based on the heritage of a much more ancient history, we must seek to find appropriate

means in order to develop surface markers and even more to ensure their conservation over long timescales. It will also be necessary, in the light of the experiments and efforts made in order to decrypt ancient messages, to find suitable expression aimed at populations in a distant future.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA), Afite (2007): *La mémoire industrielle au service des générations futures = Industrial Memory Serving Future Generations*. Symposium Tuesday December 11th, 2007. Reference: DD.TR.ADSQ.07.0032/A ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2006): *Disposal facilities: Preserving a collective memory for future generations.* ANDRA, Chatenay-Malabry.
  http://www.andra.fr/download/andra-international-en/document/editions/299.pdf
  This is one in a series of pamphlets published by Andra to explain its projects and operations to the general public. This particular pamphlet gives an overview of Andra's work, both past and ongoing, on preserving memory and knowledge of radioactive waste repositories. It notes that the purposes of this work include informing future generations of the presence of repositories to prevent inadvertent intrusion, describing the installation and potentially facilitating remedial action if required, and supporting future decisions. It gives a high-level description of what has been done to preserve information about existing facilities and studies being undertaken with respect to future geological repositories. It includes a short account of the characteristics of permanent paper. Illustrations are provided of record-keeping from the past, such as mediaeval manuscripts, the Académie Française, and long-lived monuments.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA), Charton P. (2005): *From knowledge management (KM) to memory preservation over several centuries. Experience feedback from long-term archiving at the "Centre de la Manche" (CSM) disposal facility*. Reference: SUR.TR.ADSQ.05.0029/A. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]
  Presentation at the Club of Agencies Meeting, Paris, 22-23 November 2005 (focus on knowledge management and very long term memory, with a visit of the historical archives centre from French National Archives).

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2003): *Archivage à long terme du centre de stockage de la Manche : Versement initial : Liste des résumés du contenu de chaque boîte d'archives faits pour les archives nationales de France, centre des archives contemporaines de Fontainebleau*. DOC.LI.ADSQ.03.257. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2003): *Procédure de définition et de mise en oeuvre des critères de sélection des données nécessaires à l'archivage à long terme du centre de stockage des déchets de faible et moyenne activité de l'Aube*. QUA.PR.ADCS.04.5002. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2003): Archivage à long terme du centre de stockage de la Manche: *Présentation générale de l'archivage à long terme du centre de stockage de la Manche*. [Long-term Archiving at the "Centre de stockage de la Manche" radioactive waste disposal facility (CSM): *An overall presentation of long-term archiving at the "Centre de la Manche" waste disposal facility*]. DOC.NSY.ADSQ.03.240/A. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]

A presentation of documents introducing the initial filing of the CSM's detailed memory (2004), arranged according to three levels of access to data ("understanding", "researching", "knowing").

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2003): Archivage à long terme du centre de stockage de la Manche: *Historique de l'archivage à long terme du centre de stockage de la Manche et de sa constitution*. DOC.NSY.ADSQ.03.243. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2003): Archivage à long terme du centre de stockage de la Manche: *Messages aux générations futures*. DOC.NSY.ADSQ.03.246. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2003): Centre de stockage de la Manche: *Conservation de la mémoire du centre.* DOC.NT.ADSQ.03.244. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]

- Agence nationale pour la gestion des déchets radioactifs, Haas J. (2002): *French experience in long term memory preservation for Nirex seminar on March 5th 2002*. DQ/AQ/JH QUA.TR.ADQ.02.001/A. ANDRA, Chatenay-Malabry.
  [not available online, available from ANDRA upon request]
  A presentation of memory preservation policy at Andra repositories, implemented at the "Centre de la Manche" disposal facility (CSM) and considered within the framework of the HL-LLW project.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA), Boursier F.O. (2000): Record and Archival System for the Monitoring Period of a Surface Disposal Facility. - American Nuclear Society: *WM '00: HLW, LLW, mixed wastes and environmental restoration - Working towards a cleaner environment*. Proceedings of Waste Management '00, February 27-March 2, 2000, Tucson, Arizona. American Nuclear Society, La Grange Park. Session 66, Paper 4.
  http://www.wmsym.org/archives/2000/pdf/66/66-4.pdf
  The French surface disposal facility *Centre de la Manche*, operated by ANDRA, remained in operation for 25 years. Shipments of waste packages stopped in 1994 and approval is pending for the facility's transition into its monitoring period. ANDRA has set up a structure responsible for identifying all data and documents deemed useful for the knowledge and understanding of the site. This paper presents that structure, its objectives and associated means. It also provides a detailed description of the constitution of the document collection, including sorting and identifying relevant items over the long term. The transfer of documents and data on a perennial support is also addressed, as well as details concerning archival storage. The maintenance of industrial "memory" is essential for safety purposes (in case of intervention during the monitoring period) and contributes to the improvement of public acceptance of the long-term waste management carried out at the disposal facility.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (1995): *Selection Criteria for Data Required in Long-Term Archiving for Surface Repositories (Construction, operational and monitoring phases)*. NRPAGDA95007/D. ANDRA, Chatenay-Malabry.
  [also available in French : Critères de sélection des données nécessaires à l'archivage à long terme des centres de surface (phase de construction, d'exploitation et de surveillance. N RP AGDA 95 007.]
  [not available online, available from ANDRA upon request]

A presentation of the selection criteria for the data required in understanding and maintaining the "Centre de stockage de la Manche" waste disposal facility (CSM) during its post-closure monitoring phase, especially any technical documentation relating to the repository cap, the disposal structures, the waste packages and the structures of the separate underground gravity network (RSGE), as well as the documentation concerned with environmental monitoring. It also features plausible scenarios for incidents that could occur on the site and that have determined the selection criteria.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA), Raimbault P., Valentin-Ranc C. (1993): How to mark repositories in geological formation. - *SAFEWASTE 93: International Conference on Safe Management and Disposal of Nuclear Waste*, Avignon, 13-18 June 1993, vol. 3, p. 212-221.
  [not available online – February 2011]
  This paper presents a general reflection on how to reduce the probability of inadvertent human intrusion in the future.

- Ahlen J., Ferguson F., Jackson D., McVay T., Scott L., Sexton J., Wilson D., Lewis P., Brian J., Fowler B. (1995): *Analytical Study of an Inadvertent Intrusion of the WIPP Site.* WIPP Inadvertent Intrusion Advisory Panel and New Mexico Junior College, September 5, 1995.
  [Not available at Nagra library, quoted in the WIPP CCA 1996]

- Anderson K. (2005): Designing for deep time: how art history is used to mark nuclear waste. A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Theory, Criticism and History of Art, Design and Architecture within the joint degree M.S./M.F.A. program School of Art and Design Pratt Institute October 2005.
  http://www.kellianderson.com/MSthesis.pdf
  This document is a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Theory, Criticism and History of Art, Design and Architecture. It presents a critical review of studies carried out in preparation for the design of a permanent marker system for the WIPP project. The focus is on non-linguistic visual aspects of the marker system. The primary subject of the dissertation is the work of the Markers panel documented in the Expert judgment on markers to deter inadvertent human intrusion into the Waste Isolation Pilot Plant report by Trauth et al (1993). A number of the studies that preceded and contributed to the Markers panel work are also reviewed in some detail, among them the report of the Futures panel (Hora et al 1991), as well as reports by Kaplan (1983), Sebeok (1984) and Tannenbaum (1984). Comparisons are also drawn with other studies and events, such as studies of symbols used to communicate information in public places, and the history of the Tilted Arc sculpture in New York City. The author concludes by suggesting that more thorough testing of designs should be carried out before the design is concluded and implemented.

- Aoki K., Fujii N., Kageyama H., Yoshimura K., Ohuchi J., Tsuboya T., RWMC (2008): Durable Media for Long-Term Preservation of Geological Repository Records. – *WM'08 Annual Waste Management Symposium: Proceedings*, Feb. 24 -28, 2008, Phoenix, AZ.
  http://www.wmsym.org/archives/2008/pdfs/8320.pdf
  The concept of a record preservation system should be the combination of several methods, the "Relay System" and the "Permanent System", in order to impart redundancy to the communication function. The former would maintain record preservation and communication functions in the framework of social systems whereas the latter would consist of durable storehouse facilities, recording media and markers/monuments and be independent of any social systems and human control.
  Several engraving experiments using laser technologies on durable artificial materials, such as

silicon carbide, have been performed successfully. These technologies can be applied to not only documentary records – with a 500 page document reduced to a volume of 10 cm x 10 cm x 32 cm – but also to markers and monuments.

- Bandolin G., Sörlin S. (2007): Laddade landskap – värdering och gestaltning av teknologiskt sublima platser. SKB R-07-14. Svensk Kärnbränslehantering AB (in Swedish)
  http://www.skb.se/upload/publications/pdf/R-07-14webb.pdf
  This project (November 2004-January 2006) covered the design issues and questions about the values of place and landscape in which risk and danger are important elements. Another theme related to conservation issues, protection of monuments and memories, and in such "dangerous places". An important feature of the project was to visit and describe the locations characterized by high technological experimentation and the presence of risk and danger.
  Case studies:
  - The power of the distance: Woomera, Australia.
  - The time breeds new questions: Yucca Mountain and Nevada Test Site, Nevada, USA.
  - Revaluations: Rocky mountain arsenal wildlife refuge in Denver, Colorado, USA.
  - A mansion in Eurajoki: Posiva, Finland.
  - Stories from fracture meager mountain: Forsmark and Oskarshamn, Sweden.
  - "They will come back as an idea ...": About time, monuments and landscapes.

  In connection to site visits in the USA and Australia, interviews and visits were performed to museums and other institutions and complemented by extensive literature studies.

- Battelle (1978): Institutions in long-term nuclear waste management.- *Nontechnical issues in waste management : Ethical, institutional, and political concerns*, PNL-2400. Battelle, Columbus (Ohio), Chapter IV, 43-64.
  [not available online – February 2011]
  A number of concerns have been raised regarding the role that human institutions may have to play in the long-term management of nuclear wastes. Controversy exists concerning, first of all, the need for any human institutions to be involved in long-term management; secondly,
  there is substantial uncertainty about whether human institutions could actually carry out any functions that might be required of them over the long term. The major objective of this chapter is to provide a framework for thinking about institutional issues that may be involved in the long-term management of nuclear wastes. An attempt has been made to identify organisational functions that might be needed to insure the integrity of a waste repository over several centuries.

- Benford G. (2000): Deep Time: How Humanity Communicates Across Millennia. HarperCollins (new ed.).
  [not available online, not at Nagra Library, available through Amazon]
  The author first gives a summary of the different ways that humans have intentionally left evidence of their lives long after their death. He continues to chronicle recent and ongoing efforts to leave evidence of our civilization to future humans and in outer space. The second half of the book is about how future generations will interpret the environmental state of the planet as a monument to our current society and how we can take action to change the state of the planet.

- Benford G. (1994): Comporting ourselves to the future: Of time, communication, and nuclear waste. *Journal of Social and Evolutionary Systems* 17(1), 91-113.
  [not at Nagra, available through Elsevier – ref. suggested by ANDRA]
  [Abstract]

- Benford G., Kirkwood C.W., Otway H., Pasqualetti M.J. (1991): *Ten thousand years of solitude? On inadvertent intrusion into the Waste Isolation Pilot Project Repository*. LA-12048-MS. Los Alamos National Laboratory (also reproduced in SAND 90-3063: Expert judgment on inadvertent human intrusion into the Waste Isolation Pilot Plant, App. D).
  http://www.wipp.energy.gov/picsprog/documents/Ten%20Thousand%20years%20of%20Solitude.pdf
  This report documents the work of one of four interdisciplinary teams investigating modes of inadvertent intrusion into the WIPP repository over a period of 10000 years. After identifying a series of environmental and socioeconomic changes and factors with the potential for affecting the means and likelihood of inadvertent intrusion, the team developed a wide-ranging variety of illustrative scenarios. The authors argued that while the probability of any specific scenario may be very low, this does not mean that the probability of inadvertent intrusion is low. They concluded that given the wide range of foreseeable changes that could significantly affect the likelihood of intrusion, the overall probability of intrusion is appreciable (between 1% and 25%), and also that it is possible that the consequences of such an intrusion could well surpass the consequences of an intrusion carried out with present-day technology under present conditions. The authors recommended that markers to deter intrusion be investigated and deployed at the site as a means of reducing the likelihood of future intrusion.

- Berndes S. (2001): *Wissen für die Zukunft: Ethische Normen der Auswahl und Weitergabe naturwissenschaftlichen und technischen Wissens.* Diss. Univ. Cottbus. LIT, Münster.
  [available at google.books.com]
  This dissertation addresses the issue of knowledge transfer in the field of natural sciences and technology. A case study is devoted to information management systems for the management of high-level waste.

- Berndes S., Kornwachs K. (1996): Transferring knowledge about high-level waste repositories: an ethical consideration. – *High level radioactive waste management 1996: Proceedings of the seventh annual international conference*: Las Vegas, April 29-May 3, 1996, p. 494-498.
  [not available online]

- Berry W.E. (1983): *Durability of marker materials for Nuclear Waste Isolation Site*. BMI/ONWI-474. Batelle Columbus Laboratory.
  [not available online – February 2011]
  This report reviews the probable long-term performance of materials that might be used in markers for radioactive waste repositories. The performance assessed includes not only survival of the marker itself, but also continued legibility of markings inscribed on it, by limiting the permissible depth of deterioration to 1 mm. The materials reviewed include several metals, natural stone materials, artificial stone and ceramics, plastics. Most of the materials assessed were found to be unlikely to survive a period of 10000 years, but some metals (titanium, some nickel alloys) and ceramics (SYNROC, synthetic sapphire) were identified as having good prospects for survivability. Some library materials (paper, photographic film) were reviewed for protected indoor conditions, but none were assessed to be likely to survive without periodic re-copying.

- Bloomfield B.P., Vurdubakis T. (2005): The secret of Yucca Mountain: reflections on an object in extremis. - *Environment and Planning D: Society and Space*, 23/5, 2005, 735-756.
  [not available online – June 2012]
  The processes through which boundaries are made and unmade conceptually, socially, and materially have been of enduring interest to a wide range of social scientific disciplines including sociology, anthropology, geography, science studies, etc. The subject matter of this paper, the Yucca Mountain high-level nuclear waste repository in Nye county, Nevada, constitutes a case study of such processes taken to extremes. This, in turn, makes Yucca Mountain an interesting

vantage point from which to (re)view the traditional ontological and epistemological preoccupations characteristic of social science, not so much in terms of abstract theory but rather in terms of concrete practical problems of spatial and temporal organisation. *[Abstract by authors]*

- Bowen-Shrire M., Eckerhall D., Jander H., Waniewska K. (2008): Bevarande av information om slutförvar för använt kärnbränsle – förslag till handlingsplan. SKB P-08-76, Svensk Kärnbränslehantering AB (in Swedish).
  http://www.skb.se/upload/publications/pdf/P-08-76webb.pdf

  This report is a proposal for an action plan with the ultimate aim of ensuring that information about the repository for spent nuclear fuel can be preserved and transferred for future generations. Its purpose is to present ideas on tangible measures and guidelines for information preservation and transfer, in the short and long term.

  The report deals with a number of aspects relating to information preservation as well as risks that can lead to the loss of important information. The main emphasis is on measures that need to be implemented in the near future 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, especially USA and France.
  - Participate in seminars, conferences and workgroups on an international level within the IAEA and NEA.

  In a longer time perspective the following measures should also be implemented:
  - Implement guidelines for information preservation and transfer.
  - Document the archiving system.
  - Establish a communication plan.
  - Archive information about the repository.

- Bowen-Shrire M., Jander H., Waniewska K. (2007): Kunskapsbevarande för framtiden – Fas 1. SKB P-07-220, Svensk Kärnbränslehantering AB (in Swedish).
  http://www.skb.se/upload/publications/pdf/P-07-220webb.pdf

  This report summarises the work done in the field of knowledge preservation regarding a repository for spent nuclear fuel in Sweden and in other selected countries. The purpose of the report is to provide a basis for a proposal for an action plan for knowledge preservation regarding a repository for spent nuclear fuel. The report is based upon identified key documents, interviews with key persons, and other relevant sources of information identified throughout the working process.

  The report covers the basic principles and methods for information preservation and transfer, and describes their advantages and disadvantages. The report also covers topics such as the time perspective, target groups, context, and discusses the difference between the concepts information and knowledge. The conclusions of the report include a number of recommendations for further work.

- Brenk Systemplanung GmbH (BS) (2009): *Radioactive Waste and Spent Fuel Data Collection, Reporting, Record Keeping and Knowledge Transfer by EU Member States*. Final Report. European Commission, Brussels, Belgium.
  http://ec.europa.eu/energy/nuclear/studies/doc/2009_09_radiactive_waste.pdf

  This report was prepared for the EC to document the status of the implementation of national waste data collection systems in EU member states and candidate countries. The data contained in these systems comprise the primary records collected during pre-disposal waste management. In addition to compiling information about the structures and contents of waste data collection systems, the

report also describes the legal bases, responsibilities and reporting requirements in each country. The scope includes low-level waste, high-level waste, and spent fuel if it is designated as waste. In addition to recording detailed information on the waste data collection systems in most member states and candidate countries, the report also identifies good practices and makes recommendations to the EC on possible actions for the Commission to consider in order to foster improvement in some areas where there is a lack of consistency.

- Bryan-Wilson J. (2003): Building a Marker of Nuclear Warning. – In: Nelson R.S. & Olin M. (eds.), *Monuments and memory, made and unmade*. University of Chicago Press. Chicago, pp. 183-204. [availability: see below under Nelson & Olin]
  Comments on the WIPP markers programme.

- Bundesamt für Energie, Buser M. (2010): *Forschungsprogramm Radioaktive Abfälle: Literaturstudie zum Stand der Markierung von geologischen Tiefenlagern*. BFE, Bern, Switzerland. http://www.news.admin.ch/NSBSubscriber/message/attachments/19773.pdf
  A literature study on the current status of science and technology regarding markers and more generally knowledge preservation in the field of radioactive waste management. An updated English version is in preparation under the aegis of the OECD/NEA RK&M project.

- Bundesamt für Strahlenschutz (BfS); Herzog C.; Kugel K.; Ranft M.; Regenauer U. (2011): *Erkenntnisse des BfS zum Abfallinventar der Schachtanlage Asse II: Stand: Juli 2011.* Bundesamt für Strahlenschutz, Fachbereich Sicherheit nuklearer Entsorgung, Germany.
  [not available online, available from BfS upon request]

- Clegg R., Pinner A., Smith A., Quartermaine J., Thorne M.C. (1997): Consideration of post-closure controls for a near surface low level waste disposal site. – *Proceedings of an international symposium on Experience in the Planning and Operation of Low Level Waste Disposal Facilities*: held in Vienna, 17-21 June 1996. Proceedings Series. IAEA, Vienna.
  [not available online – July 2010]
  The paper discusses potential intrusion scenarios within the framework of the programme of disposal of low level radioactive wastes by British Nuclear Fuels plc (BNFL) at Drigg, Cumbria. Although control of the site is anticipated for a period of about 100 years post-closure, eventually restrictions on access will lapse. Potential modes of intrusion into the Drigg site – leading to exposure to, and/or exhumation of, the wastes – have been studied. Although the most likely site uses, notably those involving agricultural activities, are unlikely to result in intrusion into the wastes, others, such a urban development, do have the potential to result in such intrusion. Overall, it is concluded that provided that a variety of documentary records are established, ranging from local council archives to mass produced maps, then memory of the site can realistically be assumed whilst civilisation continues to exist. However, if this first line of defence fails, markers constitute a second warning system. Finally, assessment calculations can be used to demonstrate that, even if these two lines of defence fail, risks from intrusion and radiation doses contingent upon intrusive events having occurred would not be unacceptably large.

- Codée H. (2005): Safe is beautiful. - *CNS Waste Management '05*, Ottawa, Canada, May 8-11, 2005. [not available online, June 2012]
  This paper and the following describe how the HABOG storage facilities have been built into a work of art.

- Codée H. (2003): Give the public something, something more interesting than radioactive waste. - *Proceedings of Waste Management WM '03*, February 23-27, 2003, Tucson, AZ, American Nuclear

Society, La Grange Park, Session 17, Paper #37.
http://www.wmsym.org/archives/2003/pdfs/37.pdf

- Deyo Y.E., Pauling T. (2006): Community Involvement as an Effective Institutional Control at the Weldon Spring Site, a U.S. Department of Energy Office of Legacy Management Site. – *Proceedings of Waste Management Symposium WM '06, February 26 - March 2, 2006*: Global Accomplishments in Environmental and Radioactive Waste Management: Education and opportunity for the next generation of waste management professionals.
  http://www.wmsym.org/archives/2006/prof6377.html

  The U.S. Department of Energy (DOE) Weldon Spring Site Remedial Action Project (WSSRAP) was conducted for the purpose of remediating a portion of a former trinitrotoluene and dinitrotoluene production plant that was operational from 1941 to 1945 and a former uranium refinery that was operational from 1957 to 1966. Surface remediation activities concluded in 2001 with the completion of 18 km2 on-site engineered disposal facility. In order to deal with the long-term surveillance and maintenance issues at the site, a plan was established for development of a comprehensive public involvement and education program. In August 2002, the Weldon Spring Site Interpretive Center opened to the public with exhibits about the history of the area, the remediation work that was completed, and a site information repository that is available to visitors. In addition, the Hamburg Trail for hiking and biking was constructed, including a series of historical markers. A ramp and viewing platform with informational plaques were constructed on the disposal cell. Science-oriented educational programs that directly relate to past remediation activities and present long-term surveillance and maintenance issues are presented to St. Louis area school groups and other community-based organizations. Other innovative programs have been developed to address daily maintenance issues at the site and to promote beneficial community re-use of the property.

- Drottz-Sjöberg B.M. (2010): Perceptions of Nuclear Wastes across Extreme Time Perspectives. - *Risk, Hazards & Crisis in Public Policy*, Vol. 1: Iss. 4, Article 9 (2010).
  [not available online]

  An empirical study, financed by the Swedish Radiation Authority (SSI), on perception of time, time periods, and responsibilities related to the final repository for spent nuclear fuel was conducted in 2002 in the municipalities of Oskarshamn and Östhammar. The questionnaire, included tasks of time estimates of specified historic events (e.g., when the first human landed on the moon, the development of Homo sapiens) and possible future events (e.g., a new glacial ice period, a radiation leakage from canisters in the repository). Some questions asked for risk estimations in relation to the repository, i.e., for oneself and for others in the community. Other questions inquired about perceptions of risks and responsibilities related to future generations. The overall results showed rather restricted time horizons among the respondents. Risk estimations relating to nuclear wastes were not extremely high, and as usual the risk to others rated higher than the risk to oneself. People emphasized the importance of SSI reviews in the near future in contrast to the distant future, i.e., while under operation and up to 1,000 years, rather than for the longer time periods of relevance for the reviews. People also perceived the consequences to be much more severe in the shorter time perspectives than in the longer ones, given a leakage from the canisters in the repository. The importance of future generations' life situations was reported as high, and perceived to be of greater importance to oneself than to others. The construction of a safe final repository for spent nuclear fuel ranked the highest on a list of topics when respondents indicated the responsibilities of current generations. Ranked second and third were the items "to fight criminality" and "to give children and youth a good education." [Abstract by author]

- Eng T., Norberg E., Torbacke J. (et al.) (1996): *Information, conservation and retrieval*. SKB Technical Report 96-18. Swedish Nuclear Fuel and Waste Management, Stockholm.
  http://www.skb.se/upload/publications/pdf/TR-96-18webb.pdf
  This report was prepared following a seminar on information conservation and retrieval held in Sweden in 1996. It contains two papers presented at the seminar plus a reprint of the NSK KAN-1.3 report (Jensen 1993). The first paper is by Dr. Erik Norberg, Director General of the Swedish National Archives, which describes the role and history of the national and regional archives in Sweden, discusses problems that prevent large portions of the cultural heritage from being adequately preserved, and presents an action plan to address the situation. The issues raised include failure to document events, failure to set aside documents for preservation, use of unsuitable or inadequate storage media, inadequate search tools, and intentional removal of material in the interests of efficiency and savings in administration. The second paper, by Professor Jarl Torbacke from the Department of History at Stockholm University, describes the roles of archivists and historians in preserving and maintaining a nation's identity and culture, and notes the importance of open information in a democratic society. The third paper is a reprint of a report that is included separately in this bibliography, namely Jensen (1993) "*Conservation and retrieval of information"*.

- Eng T. (1993): *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, September 5-11, 1993, vol. 2, p. 711-714.
  [not available online]
  This paper discusses a system for best possible mitigation of human intrusion. With the present knowledge, this comprise the following parts: (a) development of planning procedures for long-term conservation of gathered information (present and future national and international archives, markers etc.); (b) continuous follow up of the state-of-the-art of information media; (c) preparations for national rules and regulations on nuclear waste information; (d) participation in international cooperation on issues concerning nuclear waste information keeping, transfer and retrieval.

- Engstroem-Laarouchi S. (2010): Means to reduce human activities at the site: markers, records... where do we stand? – *Workshop: Towards transparent, proportionate and deliverable regulation for geological disposal*, Tokyo, 20-22 January 2009. OECD Nuclear Energy Agency, Issy-les-Moulineaux, p. 175-178.
  [not available online – Proceedings can be ordered from the OECD bookshop]
  The main SKB activities related to preservation of information about a geological disposal are discussed. The aim of information preservation is to avoid damage by accident and allow for our and future generations to make informed decisions. In the draft action plan, which should be presented in connection with the applications for the site selection process in [2011], suggestions on implementation of preservation of information are given. They cover the type of information of interest to be preserved, time horizons to consider as well as the potential incidents or events to envisage, their possible consequences and the measures to mitigate these consequences. Target groups are identified as well as strategies for preservation (from generation to generation, directly into a distant future). Different media for archives are envisaged. An international perspective, including international co-operation, on information preservation is also discussed.

- Environmental-Social Advisory Services (ESAS), Atomic Energy Control Board (1997): *Comprehensive review of the literature on institutional controls to limit land use*. AECB, Ottawa.
  [not available online – February 2011]
  This report documents the results of a literature survey that was conducted in order to identify case studies that would provide a basis for estimating the duration of effectiveness of institutional

controls to limit land use, and to identify attributes that contribute to the effectiveness of such controls. The literature survey was based primarily on a broad range of North American sources. The survey did not locate any case studies in North American literature of the long-term application and effectiveness of institutional controls on land use, but it did report a number of findings on the subject based on the survey. The report presents findings on a wide variety of types of institutional control over land use, both active and passive. The survey found no factual basis for believing that any form of active institutional control over land use would remain effective for longer than a few centuries at most. Passive controls such as markers and archives could survive for longer periods, but the literature suggests that their effectiveness would be problematic. The report includes an extensive bibliography of documents consulted.

- Fattah A. (1997): Requirements for records and reports related to safeguards for geological repositories. – *WM'97 : HLW, ILW, mixed wastes and environmental restoration - Working towards a cleaner environment*. Proceedings of Waste Management 97, Tucson, Arizona, March 2-6, 1997. http://www.wmsym.org/archives/1997/sess11/11-06.htm

  For effective and efficient application of safeguards, the IAEA requires vital information on facility design and operation. Part of the required information will also flow from the other obligations, e.g. safety, waste disposal, environmental protection, etc. An integrated approach to document all required information will be an advantage to all concerned. The basic safeguards approach for a geological repository will consist of continuous Design Information verification (DIV) and application of integrated safeguards verification system for inventory verification. DIV should confirm the integrity of the repository area and detect any/all undeclared activities, inter alia, the presence of sensitive equipment and tunnelling in the vicinity of the repository. As part of records keeping, the facility has to maintain records of the content and location of each spent fuel container. The IAEA and the State should retain all safeguards relevant documentation and information (i.e. records of the complete inventory of nuclear material and/or previous operations of the repository) deemed necessary. These records should be kept for at least as long as safeguards exist for the nuclear material in the repository.

- Flüeler T. (ed.) (2005): Long-term knowledge generation and transfer in environmental issues: A challenge to a knowledge bases-society: Invited session. – *PISTA 2005: The 3rd international conference on politics and information systems: Technologies and applications*, July 14-17, 2005, Orlando, Florida, USA. International Institute of Informatics and Systemics.
  [not available online – February 2011]

  This document contains the papers presented at an invited session on "Long-Term Knowledge Generation and Transfer in Environmental Issues - A Start of Intergenerational Informatics?" at the 3rd International Conference on Politics and Information Systems: Technologies and Applications, 2005. In his introductory paper, T. Flüeler sets out the basic problem and introduces a list of topics bearing on decision making. The session was organized to explore the following issues: integration of a diverse range of knowledge and interests; prerequisites of sound sustained decision making for the long term; interplay between living (current) knowledge and preserved knowledge; and the role of governance. In a paper titled "Obligation to Future Generations: The Interplay of Science and Policy", D. Metlay described the interplay of science and policy issues during the development of safety standards for disposal in the US. D. Easterling's paper titled "Incorporating the Interests of Future Generations into Nuclear Waste Policymaking: What Would They Say to Us?" investigates the ethical basis for decision making on radioactive waste and proposes a large-scale discovery process to investigate the potential for methods other than geological disposal. G. McCarthy and I. Upshall describe the potential application of contextual information frameworks to preserving the contextual information necessary to make use of preserved data in "Using Contextual Information Frameworks to Maintain Knowledge of Radioactive Waste" (see also ICA Study 18, which presents the subject in more detail). The next paper, "Why an Open Common-Knowledge Process

about Decommissioning Funds? How Transparency Supports Democracy" by M. Bovy and V. Massaut, explores ethical and philosophical issues and recommends a more broadly-based transparent decision making process for decision making on funding requirements for decommissioning. A paper titled "Knowledge Transfer - Bifunctional Method for Knowledge Conservation" by C. Fricke and B. Faust describes a two-stage process for interviewing persons in order to pass on their knowledge, explicit and implicit, to successors. In the final paper, "Long-Term Knowledge Generation and Transfer in Radioactive Waste Governance. A Framework in Response to the Future as an Enlarged Tragedy of the Commons", T. Flüeler discusses intragenerational and intergenerational equity and proposes that a working procedural approach to intragenerational equity issues could contribute to the success of a "rolling present" model for intergenerational knowledge transfer.

- Foote K.E. (1990): To Remember and Forget: Archives, Memory, and Culture. – *American Archivist*, Vol. 53, Summer 1990, 378-392.
  http://courses.ischool.utexas.edu/Winget_Megan/2010/Fall/INF381/Readings/Foote_RememberForget.pdf

  The idea of archives as collective memory is sometimes employed as a metaphor for discussing the social and cultural role of archives. It is argued here that the idea is more than a metaphor and is supported by theories that would view collections of documents and material artifacts as means of extending the temporal and spatial range of communication. Archives, along with other communicational resources such as oral and ritual tradition, help to transfer information—and thereby sustain memory—from generation to generation. Two examples illustrate the interrelationship of archives and memory within this broadened view of communication and culture. The first arises from attempts to find ways to warn future generations of the location of radioactive waste repositories. The second revolves around pressure to efface from cultural landscapes evidence of tragic events that people wish to forget.

- Garfield S. (1994): «Atomic Priesthood» is Not Nuclear Guardianship, A Critique of Thomas Sebeok's Vision of the Future. - *Nuclear Guardianship Forum*, Issue 3, On the Responsible Care of Radioactive Waste Materials, Spring 1994.
  http://www.ratical.org/radiation/NGP/AtomPriesthd.html

  A review of Thomas A. Sebeok's report to the Bechtel Group's Human Interference Task Force (1984).

- Goldman N.; Bertone P.; Chen S.; Dessimoz C.; Le Proust E.M.; Sipos B.; Birney E. (2013): Towards practical, high-capacity, low-maintenance information storage in synthesized DNA. – *Nature*; DOI: 10.1038/nature11875. Published online 23 January 2013.
  The article can be purchased at:
  http://www.nature.com/nature/journal/vaop/ncurrent/full/nature11875.html

  Digital production, transmission and storage have revolutionized how we access and use information but have also made archiving an increasingly complex task that requires active, continuing maintenance of digital media. This challenge has focused some interest on DNA as an attractive target for information storage because of its capacity for high-density information encoding, longevity under easily achieved conditions and proven track record as an information bearer. The paper describes a scalable method that can reliably store more information than has been handled before: computer files totaling 739 kilobytes of hard-disk storage and with an estimated Shannon information of 5.2×10^6 bits were encoded into a DNA code. This DNA was synthesized and sequenced, and the original files could be reconstructed with 100% accuracy. Theoretical analysis indicates that this DNA-based storage scheme could be scaled far beyond current global information volumes and offers a realistic technology for large-scale, long-term and infrequently accessed digital archiving. In fact, current trends in technological advances are

reducing DNA synthesis costs at a pace that should make this scheme cost-effective for sub-50-year archiving within a decade (Abstract: Nature online)

- Goodenough W.H. (1999): Communicating 10,000 Years into the Future. *Human Organization* 58(3), 221-225.
  http://www.sfaa.net/malinowski/monograph/malinowski.pdf#page=412
  A personal record by an anthropologist who participated in the development of the WIPP markers.

- Gowin P.; Kinker J.; Kosilov A.; Upshall I.; Yanev Y. (2009): Knowledge management for radioactive waste management organisations. *International Journal of Nuclear Knowledge Management*, Vol. 3, No. 2, p. 157-169.
  See: *International Journal of Nuclear Knowledge Management*

- Hart J. (John Hart and Associates, P.A.) (2004): *Passive Institutional Controls Implementation Plan*. Waste Isolation Pilot Plant, Carlsbad/New Mexico. DOE/WIPP 04-2301.
  http://www.wipp.energy.gov/library/PICsImplementationPlan.pdf
  This document presents an overview of the plan for implementation of the overall Passive Institutional Controls (PICs) program at WIPP. The program comprises three main elements: a records management program involving archiving of WIPP project-related documentation at a number of off-site locations; the permanent markers program at the site of the repository; and an "awareness triggers" program including dissemination of information to various agencies, post-closure control of the site by government and land use restrictions. A general description is given for each of these elements, and implementation schedules and timelines are presented. A public participation program is also outlined. The report includes attachments describing the regulatory requirements related to PICs, commitments made by DOE in fulfilment of those requirements, and commitments related to PICs made by DOE in the Hazardous Waste Facility Permit.

- Hart J. (John Hart and Associates, P.A.) (2004): *Permanent Markers Implementation Plan*. Waste Isolation Pilot Plant, Carlsbad/New Mexico. DOE/WIPP 04-3302.
  http://www.wipp.energy.gov/library/PermanentMarkersImplementationPlan.pdf
  This report is a supporting document to the WIPP Passive Institutional Controls Implementation Plan. It presents DOE plans for the design and implementation of the Permanent Markers Program including the establishment of performance specifications, determination of testing needs, and definition of a strategy for making design decisions. A brief overview of the regulatory requirements and commitments is given, followed by an outline of the markers design process, including performance and design criteria. There are six components of the permanent marker system: large surface markers, small subsurface markers, a berm, buried storage rooms, the hot cell (an existing structure to be left as a permanent monument), and an information center. For each of these components, a conceptual design is presented, "open design considerations" (aspects of the design that have not yet been finalized) are listed, and alternative materials are listed. The development of messages to be inscribed on or contained in various marker system components is outlined. Program management activities and the quality assurance program are briefly described.

- Hart J. (John Hart and Associates, P.A.) (2000): *Permanent Markers Monument Survey: Contractor report*. Waste Isolation Pilot Plant, Carlsbad (New Mexico).
  http://www.wipp.energy.gov/picsprog/documents/monument%20survey.pdf
  This document describes a survey of prehistoric inscriptions in rocks in New Mexico and neighbouring Texas. The survey was carried out in order to determine how well various rock types within climatological zones similar to that of the WIPP site have performed as media for inscriptions in terms of both legibility and durability. Sites chosen were limited to rock types that have been proposed for use in permanent markers, in similar climatological conditions, and that

have not undergone major restoration or artificial preservation. Rock properties, inscription characteristics, apparent ages of inscriptions and the effects of weathering and erosion were studied. Conclusions are presented on the durability of various rock types encountered, on the effects of aspect and rates of erosion, on the effects of the form of the inscriptions, and on the importance of contrast in colour and texture, and recommendations are made on rock type and form of inscriptions that might be used for permanent markers at WIPP. The report includes photographs and site reports from the sites studied.

- Hart J. (John Hart and Associates, P.A.) (2000): *Permanent Markers Material Analysis: Contractor report*. Waste Isolation Pilot Plant, Carlsbad (New Mexico).
  http://www.wipp.energy.gov/picsprog/documents/Materials%20Analysis.pdf
  This report presents the results of a literature review on materials proposed or suggested for use in a permanent marker system at the WIPP repository. The objectives of the review were to identify materials that could be suitable for each marker system, to evaluate these materials based on information available in the literature and from expert opinion, to recommend materials that appear to be best suited for specific marker applications, and to identify tests most appropriate for the screening phase of the testing program. The material design criteria adopted in the WIPP Permanent Markers Implementation Plan are described. Materials specified in the reference design as well as alternative materials identified both before and during the literature review are described and analyzed vis-à-vis the design criteria. Comparisons are presented between candidate materials for each marker component. Conclusions and recommendations for the first level of material selection and testing in the screening phase of the permanent markers testing program are provided.

- Hart J. (John Hart and Associates, P.A.) (2000): *Ancient Cementitious Materials: Contractor Report.* Waste Isolation Pilot Plant, Carlsbad (New Mexico).
  http://www.wipp.energy.gov/picsprog/documents/Ancient%20Cementitious%20Materials.pdf
  This report describes a literature review of instances in which man-made cementitious materials have survived for very long time periods. Case studies of long-lived concrete structures are provided. The report documents attributes of the cementitious materials that promoted their survival. It demonstrates that there are examples of the use of man-made cementitious materials that have survived for as long as 8800 years. The report concludes that it should be possible to produce a concrete that will survive for a period of 10,000 years when used as a construction material for markers or monuments.

- Health and Safety Executive, United Kingdom (2010): *The management of higher activity radioactive waste on nuclear licensed sites: Part 3d: Managing information and records relating to radioactive waste in the United Kingdom*. Joint guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees.
  http://www.hse.gov.uk/nuclear/wastemanage/rwm-part3d.pdf
  This document is one component of regulatory guidance provided by the regulatory authorities in the United Kingdom to organisations responsible now and in the future for the management of high- and intermediate-level radioactive waste. It covers the topic of management of information and records for radioactive waste from its generation up to the end of regulatory control. This period is recognised to be in the hundreds of years. It contains general guidance on information and records management policy, strategy, systems and procedures, including risk management and backup procedures. Transfer of records to other organisations in time is also addressed. It includes discussions on records media and on records storage facilities and archives. There is a general guidance on the nature of the information, records and metadata to be managed. Processes for periodic review of records holdings and for security and the protection of sensitive information are covered. The document also includes a list of references to national legislation, regulatory policies

and guidance, and relevant national and international standards, e.g., in the field of archiving. (rev. CP)

- Holtorf C., Högberg A. (2014): Communicating with future generations: what are the benefits of preserving cultural heritage? Nuclear power and beyond. - *European journal of Post - Classical Archaeologies*, PCA 4/2014.
  [Not available online – 10.04.2014]
  Using the example of the legacy of the nuclear power station at Dounreay, this paper discusses what it means to preserve something for the benefit of future generations.

- Hora S.C., von Winterfeldt D., Trauth K.M. (1991): *Expert judgment on inadvertent human untrusion into the Waste Isolation Pilot Plant*. SAND90-3063. Sandia National Laboratories, Albuquerque.
  http://www.wipp.energy.gov/picsprog/Test1/SAND90-3036%20Expert%20judgement,%20human%20intrusion.pdf
  This report describes the studies carried out by four multi-disciplinary expert teams (the "Futures Panel") to develop scenarios illustrating the possible development of future societies in the vicinity of the WIPP repository, and potential modes and likelihoods of human intrusion into the repository. Each of the four teams developed a methodology for delineating possible future societies and the possibilities for intrusion into the repository under those societies. The purpose of these scenario developments was to provide background information for later work to design markers, barriers and off-site information systems in order to deter future intrusion into the repository, or to mitigate its consequences. The intrusion scenarios identified by the four teams were highly varied, and served to alert subsequent design groups to the need to consider a very wide range of possibilities when designed markers and barriers. Each of the teams also developed quantitative estimates of the probability of various types of intrusion, as input to subsequent performance assessments.

- Hora S.C., von Winterfeldt D. (1997): Nuclear Waste and Future Societies: A Look into the Deep Future. - *Technological Forecasting and Social Change* 56(2), 155-170.
  [available for purchase through Elsevier]
  Inadvertent human intrusion is thought to be a significant, if not the most significant, threat to nuclear waste held in repositories. As part of the effort to access the safety of the first United States repository, the Waste Isolation Pilot Plant near Carlsbad, New Mexico, four interdisciplinary teams of experts were brought together to provide insights into the modes and likelihoods of such intrusions as far as 10,000 years in the future. A formal expert elicitation process was used in obtaining their judgments. The teams provided scenarios that, although formed using different approaches, reflected several central themes. These themes are the uncertainty about the need for resource exploration in the future, the rate at which technology develops or declines in future, the likely failure of government control of radioactive waste sites, and the preservation and potential loss of memory about nuclear waste. Identifying possible futures enhances the ability to construct a repository that will be robust against many different potential threats. *[Abstract: Elsevier website]*

- Human Interference Task Force, HITF (1984): *Reducing the likelihood of future human activities that could affect Geologic High-Level Waste Repositories*. BMI/ONWI-537. Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio
  http://www.osti.gov/bridge/servlets/purl/6799619-fpYg48/6799619.pdf
  This report documents the methods used by and the findings of the Human Interference Task Force. The Task Force was convened by the U.S. Department of Energy to determine whether means exist or could be developed to reduce the likelihood of future inadvertent intrusion into or interference with radioactive waste repositories. The report discusses siting, land use and institutional controls as one component of a multi-faceted approach to preventing intrusion. It

describes and discusses various aspects that contribute to the reliability of communication of messages at varying levels of complexity, and recommends the use of permanent markers, both surface and sub-surface, and of the collection and wide dissemination and storage of records about the repository and its contents. The report contains recommendations on the design of several types of markers and on the development, collection, distribution and archiving of records intended to inform future generations of the nature of the repository and hazards that would be posed by intrusion. The task force also recommended the establishment and use of a universal symbol to denote the presence of biohazardous waste. The task force concluded that significant reductions in the likelihood of human interference could be achieved that might be effective for as long as thousands of years after closure, by taking appropriate steps to communicate the existence of the repository to future generations. The report recommended further study on the effectiveness of various types of messages, on durability of messages and marker materials, and on mechanisms for transmission of messages.

- Husemann D. (2104): Das Archiv für die Ewigkeit. – Bild der Wissenschaft, 4, 2014, 60-66.
  Summary available at: http://www.wissenschaft.de/highlights/-/journal_content/56/12054/3256909/Gegen-das-Vergessen/
  Description of the project „Memory of Mankind“.

- International Atomic Energy Agency (in preparation): *Knowledge management for radioactive waste management organisations.* IAEA NW-***. IAEA, Vienna.
  [to be published in 2013]

- International Atomic Energy Agency (2012): *Knowledge management for nuclear research and development organizations*. IAEA-TECDOC-1675. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/TE_1675_web.pdf
  The IAEA nuclear knowledge management activities assist in transferring and preserving knowledge, exchanging information, establishing and supporting cooperative networks, and training the next generation of nuclear experts. This publication has been developed to address the specific needs of nuclear research and development and technical support organizations, which have unique features that are not captured in previously published reports. Its declared purpose is to provide assistance to decision makers from nuclear research and development organizations on planning, implementing and sustaining knowledge management programmes to derive business benefit, i.e. in a short-term perspective. However, the tools described in the report can be used with a longer timeframe in mind.

- International Atomic Energy Agency (2011): *Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation*. NG-T-6.7. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1494_web.pdf
  This publication draws on the results of a coordinated research project on comparative analysis of methods and tools for knowledge preservation in nuclear organizations. The project was initiated by the IAEA in order to enhance the capacity of Member States to maintain and preserve the information and knowledge resources related to the peaceful uses of nuclear energy. The project participants explored methods and tools used to capture, interpret, analyse and disseminate data and information, as well as the knowledge ultimately derived from them. Furthermore, a survey tool on the current status of knowledge preservation in nuclear and supporting organizations was developed. The analysis of the survey served as a basis for the recommendations and conclusions on good practices in knowledge preservation.

- International Atomic Energy Agency (2011): *Disposal of Radioactive Waste, Specific Safety Requirements*. IAEA Specific Safety Requirements SSR-5, IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1449_web.pdf
  See in particular provisions listed under Requirement 3 "Responsibilities of the operator", Requirement 14 "Documentation of the safety case and safety assessment" and Requirement 22 "The period after closure and institutional controls".

- International Atomic Energy Agency (2010): *Technological implications of international safeguards for geological disposal of spent fuel and radioactive waste*. IAEA Nuclear Energy Series NW-T-1.21. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1414_web.pdf
  This report provides an overview of the technological implications of international safeguards at a generic geological repository containing spent fuel and radioactive waste during its design, construction, operation and post-operational phases. Prior to closure, these are in broad outline similar to those applicable to other nuclear facilities. The particular measures put in place would include measures specific to the design of the repository and its site, as well as measures common to other nuclear facilities in the country. These safeguards measures should be incorporated into repository design and planning from the outset. Following closure, while safe evolution of a geological repository must not be reliant on continuing, active, institutional control, the requirement to apply IAEA safeguards could necessitate a long term inspection regime which might continue post-closure. This inspection regime would be site-specific, and could involve remote surveillance and geophysical monitoring which would be dependent on the continued existence and accessibility of safeguards-relevant information about the repository.

- International Atomic Energy Agency (2010): *Governmental, legal and regulatory framework for safety*. General Safety Requirements. IAEA Safety Standards No. GSR Part 1. IAEA, Vienna. [supersedes IAEA 1995, 111-S-1]
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1465_web.pdf
  This publication covers the essential aspects of the governmental and legal framework for establishing a regulatory body and for taking other actions necessary to ensure the effective regulatory control of facilities and activities. It highlights in particular which records must be available and/or created in the framework of regulatory activities.

- International Atomic Energy Agency (2009): *Predisposal Management of Radioactive Waste, General Safety Requirements Part 5*. IAEA General Safety Requirements GSR Part 5. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1368_web.pdf
  See in particular provision 3.11, where maintenance of records and recording are listed among measures to ensure an adequate level of protection and safety.

- International Atomic Energy Agency (2008): *The management system for the disposal of radioactive waste*. IAEA Safety Guide GS-G-3.4. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1330_web.pdf
  See in particular provisions listed under the heading "Control of records", 5.47 – 5.54. Topics addresses include content and retention of records, recording media and record keeping, as well as transfer of information between organisations and to future generations.

- International Atomic Energy Agency (2008): *The Management System for the Processing, Handling and Storage of Radioactive Waste*. IAEA Safety Guide GS-G-3.3. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1329_web.pdf

See in particular provisions listed under the heading "Control of documents", 5.39 – 5.59. Topics addressed include content and retention of records, recording media and record keeping, as well as transfer of information between organisations.

- International Atomic Energy Agency (2008): *Long Term Preservation of Information for Decommissioning Projects*. Technical Reports Series No. 467. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/trs467_web.pdf

  This report is intended to provide guidance on the approaches and technologies that can be used for the organization, maintenance, and later use of records that span a wide range of time and operating environments for the purposes of decommissioning nuclear facilities. While it makes reference to and is not inconsistent with other IAEA documents dealing with records keeping for waste management and disposal, that is not within its scope. There is a particular focus in the report on a number of practical issues to ensure that the necessary information is preserved. This refers not only to the physical preservation of information, but also to its legibility and to the skills needed to understand its technical meaning. It includes a description of some records management tools, including both records management systems and document management systems, outlining the strengths and weaknesses of each of these types of records management application. It goes into some detail on issues of physical management of records, including such topics as long-term reliability and accessibility of media, storage facilities, maintenance, protection and security including disaster recovery, and criteria for destruction of records that are no longer needed. It also discusses human aspects of knowledge preservation and transfer, such as succession and recruitment planning and retention of nuclear knowledge necessary for a decommissioning project that could take many decades for its completion. It includes appendices describing national and international initiatives for nuclear knowledge management, on media and hardware considerations for long term preservation of records, and making recommendations for further research on long term preservation. There are extensive annexes describing national experiences with record keeping for decommissioning and examples of lessons learned from that experience.

- International Atomic Energy Agency (2008): *Planning and Execution of Knowledge Management Assist Missions for Nuclear Organisations*. IAEA-TECDOC-1586, IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/TE_1586_web.pdf

  The General Conference of the IAEA has adopted resolutions on Nuclear Knowledge that request the IAEA to develop corresponding activities. Current activities in KM aim to further increase the level of attention and awareness given to activities for preserving and enhancing nuclear knowledge; to assist Member States to ensure the preservation of nuclear experience and competence needed for the effective and safe use of nuclear energy; to promote the networking of institutions for nuclear education and training; to evaluate the relevance of current programs and activities regarding nuclear knowledge, and to identify approaches aimed at how best to address the problems. The IAEA is implementing a special subprogram on Nuclear Knowledge Management with a focus on the development of guidance for KM, on networking nuclear education and training and on the preservation of nuclear knowledge.

  In the IAEA context, knowledge management is defined as:

  "An integrated, systematic approach to identifying, acquiring, transforming, developing, disseminating, using, sharing, and preserving knowledge, relevant to achieving specified objectives. Knowledge management helps an organization to gain insight and understanding from its own experience. Specific activities in knowledge management help the organization to better acquire, store and utilize knowledge."

  This document provides a common framework for KM missions and to provide general guidance for all mission participants.

- International Atomic Energy Agency (2007): *Retrieval, Restoration and Maintenance of Old Radioactive Waste Inventory Records*. IAEA-TECDOC-1548. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1548_web.pdf
  This report was prepared by the IAEA to provide guidance to waste management organisations and regulators on developing a methodology for the retrieval, assessment, verification and restoration of waste inventory records for waste management facilities where the records are either lost or inadequate, and for the transfer of these records into a records management system that meets current internationally accepted standards. The scope of the report includes both conditioned and unconditioned low- and intermediate-level waste and waste packages, including disused sealed sources, either in managed interim storage sites or in disposal sites that are no longer considered to meet acceptable standards and must as a result be remediated. The report gives a number of examples of problems encountered in retrieval of records for repositories and other waste management sites, and describes a number of the needs for improvement of existing records, particularly in order to meet the requirements of the Joint Convention. It sets out a methodological framework for retrieval of waste inventory records, including establishment of a stepwise approach, prioritization of data retrieval steps, establishment of an approach for assessing the reliability of records, implementation of these steps, and data verification and validation. The methods are based on experience gained in a number of countries, and are illustrated with examples from that experience.

- International Atomic Energy Agency (2007): *International conference on knowledge management in nuclear facilities*, 18-21 June 2007. IAEA, Vienna
  Book of extended synopses available at:
  http://inisdb.iaea.org/inis/php/download.php?s=p&rn=38067938
  This reference is a collection of extended synopses of papers presented at the conference. The majority of the papers describe what is being done in various organisations to transfer knowledge, both explicit and implicit, from ageing and retiring staff at nuclear facilities to their successors. Two of the papers relate to information transfer about waste repositories and waste disposal: "Knowledge management in the Japanese high-level waste disposal programme" by T. Kawata et al, and "Transfer of radioactive waste disposal knowledge to future generations: A stiff challenge for universities", by B.B. Sabet and F.J. Elorza.

- International Atomic Energy Agency (2007): Drop it and run! New symbol warns of radiation dangers and aims to save lives. - *IAEA Bulletin* 48 / 2, 70-72.
  http://www.iaea.org/Publications/Magazines/Bulletin/Bull482/48202087072.pdf
  Presentation of a new symbol to help warn people about the dangers of radioactive sources.

- International Atomic Energy Agency (2006): *Risk management of knowledge loss in nuclear industry organisations*. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1248_web.pdf
  This publication addresses knowledge management tools and processes intended for use in nuclear power plants, in order to mitigate the risk of knowledge loss caused by the departure of experienced staff. These tools and processes could also, to a certain extent, be used in the area of waste disposal.

- International Atomic Energy Agency (2006): *Knowledge management for nuclear industry operating organizations*. IAEA-TECDOC-1510. IAEA, Vienna.
  http://www.iaea.org/inisnkm/nkm/documents/te_1510_web.pdf
  This report provides information on the application of knowledge management approaches and practices in nuclear industry organizations. Knowledge management is succinctly described as the process through which organizations generate value from their intellectual and knowledge-based

assets. Thus it represents one facet or aspect of an organization's overall management processes, systems and corporate culture. Knowledge management policies and strategies, practices, methods and techniques are described and explained in detail. Recommendations are made for further international initiatives aimed at providing support to nuclear organizations seeking to incorporate knowledge management methods within their management systems. A large number of appendices are included describing existing applications of knowledge management in nuclear organizations. These cover topics such as knowledge capture and transfer, knowledge dissemination, workforce and succession planning, and management techniques. A glossary of definitions of terms used in the knowledge management field is also included.

- International Atomic Energy Agency (2006): *Data Requirements and Maintenance of Records for Spent Fuel Management: A Review*. IAEA-TECDOC-1519. IAEA, Vienna. http://www-pub.iaea.org/mtcd/publications/pdf/te_1519_web.pdf

  This report is a review of requirements for data collection and management for spent nuclear fuel throughout its life cycle from fuel fabrication to reprocessing or disposal. Several different life cycle possibilities are considered, including direct disposal as well as various reprocessing or partitioning and transmutation options. Data requirements described include those related to operational needs, to safeguards obligations, to safety and licensing, and to meet international obligations such as reporting under the Joint Convention. Details are given on the kinds of data parameters that need to be recorded, including identification of the radioisotopes most important to post-closure safety of a repository. Information is provided on data management, including responsibilities and development and maintenance of databases. An appendix describes disposal-relevant data requirements for spent LWR fuel, and there are several annexes containing reports from a number of countries on current practices for spent fuel data management.

- International Atomic Energy Agency (2006): *The Management System for Facilities and Activities*. IAEA Safety Standards No. GS-R-3. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1252_web.pdf

  This is the IAEA consensus safety standards Requirements document that describes the requirements for establishing, implementing, assessing and continually improving a management system that integrates safety, health, environmental, security, quality and economic elements to ensure that safety is properly taken into account in all the activities of an organization. It replaces previously published quality assurance requirements. Its scope covers the entire range of activities involving radioactive material, from major nuclear facilities to activities involving the use of radioactive sources, throughout their life cycles from initial siting and design up to decommissioning or closure. It does not define the specific requirements for safety applicable to these activities, but rather the requirements for managing the fulfillment of those safety requirements by both operating organizations and regulatory bodies. It describes the general requirements for a management system, management responsibility, management of resources, management of processes, and management of monitoring, assessment and improvement.

- International Atomic Energy Agency (2006): *Managing nuclear knowledge.* Proceedings of a workshop, Trieste, 22-26 August 2005. STI/PUB/1266. IAEA, Vienna. http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1266_web.pdf

  This is the proceedings of a workshop on nuclear knowledge management organised in response to recent trends, such as an ageing workforce, declining student enrolment and the risk of losing accumulated nuclear knowledge and experience. The challenges and solutions described in the papers apply to the nuclear industry generally and relate to the transfer of knowledge from current operating staff to their immediate successors, or to programmes organised in concert with educational institutions to address the training needs of the nuclear industry. The workshop included sessions on policies and strategies in nuclear science and technology, managing nuclear

information resources, human resources and knowledge transfer in the nuclear sector, managing and preserving knowledge in the nuclear sector, networking for education, training and knowledge transfer. The papers presented at the workshop are included in the proceedings.

- International Atomic Energy Agency (2006): *Managing nuclear knowledge: Strategies, information management and human resource development*, 7-10 September 2004, Saclay, France. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1235_web.pdf

  This is the proceedings of a conference, with summaries and conclusions of all of the sessions, but not including copies of the papers presented. The objective of the conference was to reach a clear and common understanding of the issues related to nuclear knowledge management for sustaining knowledge and expertise in nuclear science and technology, in response to recent trends such as workforce ageing and declining student enrolment numbers, and the risk of losing accumulated knowledge and experience. The focus was on transfer of knowledge from staff at nuclear facilities to their immediate successors and on networking with educational institutions for capacity building.

- International Atomic Energy Agency (2005): *Methods for maintaining a record of waste packages during waste processing and storage*. Technical Reports Series 434. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/TRS434_web.pdf

  This report is intended to provide guidance on current best practices for maintaining records of waste packages produced through various phases of the waste management process from waste generation through conditioning, storage and transport, until receipt of the waste packages at a disposal facility. Post-closure record-keeping is not addressed. The records in question include both records describing individual waste packages, and records describing the performance, operations and management systems of the organizations responsible for waste management. The report describes requirements, responsibilities and the main components of a records management system for waste packages. It includes appendices on available technologies for record storage, data transfer and waste package identification; suggested minimum contents of both package-oriented and process-oriented records; responsibilities for data generation and retention of various types during the waste package life cycle; and guidance for institutional waste generators such as hospitals and industrial radiographers.

- International Atomic Energy Agency (2005): *Standard Format and Content for Safety Related Decommissioning Documents*. Safety Reports Series No. 45. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1214_web.pdf

  This report provides practical information to the regulatory body and the operator on the safety related documents that need to be prepared to support the decommissioning process. These documents include the decommissioning plan and other supporting documents. Management of operational waste and spent fuel is outside the scope of this report. The document presents a typical table of contents for a decommissioning plan and gives detailed guidance on the contents of each section of the plan. A management plan for wastes arising during the decommissioning process is described, but the eventual disposal of those wastes is beyond the scope of the report. In addition to the decommissioning plan, a number of supporting documents, such as characterization plans and reports, radiological survey plans and reports, policies and procedures, public relations plans, and the final decommissioning report, are also described.

- International Atomic Energy Agency (2004): *Records for radioactive waste management up to repository closure: Managing the primary level information (PLI) set*. IAEA-TECDOC-1398. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/te_1398_web.pdf

The purpose of this report was to raise international awareness of the need to identify and manage pre-closure records in a manner that both serves the operational needs of a repository and the need to identify and transfer relevant information to future generations in a systematic manner. It provides an overview of the various records that could be generated up to repository closure and describes the need to identify the relevant records that are likely to be of value for future generations. It also describes the importance of the early establishment of a coordinated, integrated and well managed primary level information set. Noting that waste often passes through a number of organisations between its generation and disposal, it points out the need for a single comprehensive records management system to ensure information is preserved through the transfers. It also describes information management considerations that need to be addressed by a records management system.

- International Atomic Energy Agency (2004): *Maintaining Knowledge, Training and Infrastructure for Research and Development in Nuclear Safety*. INSAG Series 16. IAEA, Vienna. http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1179_web.pdf

  In 1999 INSAG (International Safety Advisory Group) stated the following principle: "Organizations concerned [should] ensure that operating experience and the results of research relevant to safety are exchanged, reviewed and analysed, and that lessons are learned and acted on." The purpose of this report is to emphasize the importance of maintaining capabilities for nuclear research and education, especially with regard to safety aspects, so that nuclear safety may be maintained in IAEA Member States, and to alert Member States to the potential for significant harm if the infrastructure for research, development and education is not maintained.

- International Atomic Energy Agency (2003): *Predisposal management of high level radioactive waste: Safety guide*. IAEA Safety Standards Series WS-G-2.6. STI/PUB/1151. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1151_web.pdf

  This is the IAEA consensus safety standards Guidance document that provides recommendations on how to meet the safety requirements for the predisposal management of high level radioactive waste from nuclear fuel cycle facilities and large research and development installations. The scope includes high level wastes arising from decommissioning of nuclear facilities and activities, including spent fuel where that is considered a waste. The scope is limited to predisposal management and does not include disposal facilities. The guide includes recommendations related to the requirements for protection of human health and the environment, roles and responsibilities of operators and regulatory bodies, safety considerations for waste management and decommissioning, including preparation of documentation, safety features of waste management facilities and equipment, record keeping and reporting, safety assessment, and quality assurance. The document also includes an Appendix describing the key properties and characteristics of high level waste, development of waste package specifications, and Annexes describing features, events and processes relevant to safety assessments for the management of high level waste.

- International Atomic Energy Agency (2003): *Record keeping for the decommissioning of nuclear facilities: Guidelines and experience*. Technical Reports Series 411. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/TRS411_scr.pdf

  This report provides information on how to identify, update as needed and maintain the necessary records to assist in the decommissioning of nuclear facilities. The records in question are generated and collected during the design, construction, operation, shutdown and post-shutdown phases of the facility prior to the completion of decommissioning. Record keeping for radioactive waste management and disposal facilities is outside the scope of this report. Advice is given on the selection of records to be retained from earlier life-cycle phases as well as from decommissioning activities themselves. Guidance is given on the establishment and maintenance of a records management system for decommissioning purposes, including periodic auditing. An appendix

describes options for record storage media and retrievability. There are extensive annexes describing various national experiences with record keeping related to decommissioning.

- International Atomic Energy Agency (2003): *Predisposal management of low and intermediate level radioactive waste*. Safety guide. IAEA Safety Standards Series No. WS-G-2.5. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1150_web.pdf

  This is the IAEA consensus safety standards Guidance document that provides recommendations on how to meet the safety requirements for the predisposal management of low and intermediate level radioactive waste from nuclear fuel cycle facilities, large research and development installations and radioisotope production facilities. The scope includes wastes arising from decommissioning of nuclear facilities and activities, but excludes wastes from uranium mining and milling. The scope is limited to predisposal management and does not include disposal facilities. The guide includes recommendations related to the requirements for protection of human health and the environment, roles and responsibilities of operators and regulatory bodies, safety considerations for waste management and decommissioning, including preparation of documentation, safety features of waste management facilities and equipment, record keeping and reporting, safety assessment, and quality assurance. The document also includes Annexes describing the nature and sources of low and intermediate level waste, development of waste package specifications, and features, events and processes relevant to safety assessments for the management of low and intermediate level waste.

- International Atomic Energy Agency (2002): *Documentation for Use in Regulating Nuclear Facilities*. IAEA Safety Standards Series No. GS-G-1.4. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1132_scr.pdf

  This is the IAEA consensus safety standards Guidance document that provides recommendations on how to meet the safety requirements for documentation relating to the regulatory and authorization process for nuclear facilities. The scope includes the life cycle of all kinds of nuclear facilities including waste repositories, but in the case of repositories it is limited to the stages up to and including closure, i.e. the end of direct regulatory control. The guide includes recommendations related to regulations and regulatory guides, to documents prepared by operators in fulfillment of regulatory requirements, and to documents produced for a specific facility by the regulator, including licences and licence conditions. The document also includes an Appendix describing the regulatory approval and authorization process in general.

- International Atomic Energy Agency (2002): *Issues relating to safety standards on the geological disposal of radioactive waste*: Proceedings of a specialists meeting held in Vienna, 18-22 June 2001. IAEA-TECDOC-1282. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1282_prn/t1282_part1.pdf
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1282_prn/t1282_part2.pdf

  This document contains the proceedings of a specialists meeting held in Vienna in June 2001, including summaries and conclusions of each of the sessions as well as the papers presented in the sessions. Session titles were: “Common framework for radioactive waste disposal”; “Making the safety case - demonstrating compliance”; “Safety indicators”; “Reference critical groups and biospheres”; “Human intrusion”; “Reversibility and retrievability”; and “Monitoring and institutional control”. In the summary of the last session, it was noted that the current generation has a limited ability to ensure that disposal will be implemented according to the current plan, and that each generation will make its own plans with respect to the use and closure of the repository. Each generation has the responsibility to pass down to the next generation the information, skills and knowledge needed to make informed decisions, and further consideration should be given to mechanisms for achieving the transfer or passing down of information between generations. In the final paper in that session, “Radiation protection activities after closure of geological repositories”,

M. Jensen and P. Wallberg point out that a large body of environmental monitoring information is already being built up, and this represents another source of information to be passed down to future generations. See in particular Appendix A.6. Human intrusion, A.7. Reversibility and Retrievability, A.8. Monitoring and Institutional Control as well as the corresponding chapters 2.5, 2.6, 2.7, 4.2, 4.3 and 4.4.

- International Atomic Energy Agency (2001): *Waste Inventory Record Keeping Systems (WIRKS) for the management and disposal of radioactive waste*. IAEA-TECDOC-1222. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/te_1222_prn.pdf

  This document is intended to provide technical guidance on the establishment of a waste inventory record keeping system (WIRKS), as well as presenting a methodology for the compilation and management of records in such a system. A WIRKS is considered to be a subset of the primary level information that would be gathered when waste is generated and during the pre-closure phases of the life cycle of a repository. While some of the information in a WIRKS may become part of the post-closure records, this document does not explicitly discuss the post-closure phase. The scope of the report includes both low-level and high-level waste. The document discusses the reasons why a WIRKS is needed during repository design, construction and operation, and provides technical guidance on the kinds of technical information that should be recorded for each waste package, as well as associated documentation (metadata). It also discusses responsibilities for and gives suggestions on the implementation and management of a WIRKS. The report contains several case studies on experience with WIRKS systems in a number of countries.

- International Atomic Energy Agency (1999): *Maintenance of records for radioactive waste disposal*. IAEA-TECDOC 1097. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/te_1097_prn.pdf

  This document was prepared in order to advise national programmes on ensuring the retention and availability of information for future generations post-closure, and on a methodology for the compilation and long term management of records. The scope covers both near surface and geological disposal. The report describes the information needs of future generations and lists the essential elements of a records management system to meet those needs. It describes a hierarchical relationship between the high level information (HLI) needed by future generations, the intermediate level information required for licensing, and the primary level information generated during siting, design, construction and closure. It describes the types and content of records that should be collected in an HLI, and sets out the structure of a records management system, the organisation and responsibilities involved in its establishment and maintenance, and key issues to be addressed. The report includes an Appendix describing technical options for record media and retrievability.

- International Atomic Energy Agency, Working Group on Principles and Criteria for Radioactive Waste Disposal (1996): *Issues in radioactive waste disposal: second report*. IAEA-TECDOC-909. IAEA, Vienna http://www-pub.iaea.org/MTCD/publications/PDF/te_909_web.pdf

  This is the second in a series of three reports on issues and concepts in the area of waste disposal by the IAEA's Working Group on Principles and Criteria for Radioactive Waste Disposal. Three topic areas are discussed: potential actions for the purpose of ensuring the continuing safety of geological repositories in the post-closure period; a review of issues in the optimization of radiation protection for waste disposal; and issues related to the interface between safeguards and radioactive waste management. Post-closure issues discussed in the document include the preservation of information and knowledge, public reassurance, and prevention of misuse of repository contents. The following chapter discusses a number of difficulties that arise in the application of the optimization concept in radiation protection to waste disposal, particularly in

light of the very long time scales involved and the inter-generational ethical considerations that arise in consequence. The final chapter deals with the potential for incompatibilities between safeguards concerns and safety considerations, both prior to and following closure of a repository. In general, the purpose of this document is to raise and present questions for further consideration, rather than to reach conclusions or propose potential solutions.

- [International Atomic Energy Agency (1995): *Establishing a national system for radioactive waste management*. IAEA Safety Series No. 111-S-1. IAEA, Vienna. Superseded by IAEA 2010, GRS Part 1]

- International Council on Archives, McCarthy G., Upshall I. (2006): Radioactive Waste Information: Meeting our obligations to future generations with regard to the safety of waste disposal facilities. ICA Study 18. ICA, Paris.
  http://www.wien2004.ica.org/sites/default/files/Study%2018%20Final%20version%20PDF.pdf
  This report documents the results and conclusions of a study conducted under the auspices of the IAEA in 2002 to examine the critical importance of the preservation and transfer of information in ensuring the safety of radioactive waste disposal facilities for future generations. This study, published by the International Council on Archives (ICA), is almost identical to a report that was submitted to the IAEA under a different title, but never released. Although issues related to information media and the preservation environment are discussed, the report is focused on the challenge of preserving information such that it may be successfully comprehended by future generations. In this respect, preservation of the knowledge necessary to explain the context, structure and meaning of information is critical to prevent epistemic loss. Indeed, information is always created in a context delimited by both time and space: it therefore needs to be assessed in relation to a variety of parameters that will influence the meanings that can be derived. Such parameters – such as the administrative structures, the governance framework, the financial arrangements, the regulatory environment, the status of scientific and technological knowledge, the evolution of the physical environment, the attitudes of special interests groups and the concerns of the community as a whole – should be systematically captured and preserved, and used to establish decentralised contextual information frameworks, starting at the local level. Open network public information infrastructure technologies such as the Internet and the World Wide Web may provide a means by which local frameworks could be linked to build a global framework of radioactive waste information.
  The report also highlights specific archival issues. In light of the particular needs posed by radioactive waste information, archival collection policies and appraisal practices may need to be reconsidered. The relationships between nuclear industry based archival programs and national archives should be examined. To assist archives gather and use contextual information in a systematic and interoperable manner, the ICA developed the "International Standard for Archival Authority Records (Corporations, Persons and Families)". Taking this as a starting point, this study explores what might be achieved if the concept of contextual information management is extrapolated into the realm of open networked public knowledge. (rev. AC)
  (see also Upshall & McCarthy 2007)

- *International Journal of Nuclear Knowledge Management*, Vol. 3, No. 2, 2009. Special issue on Nuclear Knowledge Management: IAEA Perspective.
  [not available online, can be purchased from Inderscience Publishers, http://www.inderscience.com/info/inarticletoc.php?jcode=ijnkm&year=2009&vol=3&issue=2]
  Includes in particular: Gowin P.; Kinker J.; Kosilov A.; Upshall I.; Yanev Y. (2009): Knowledge management for radioactive waste management organisations, p. 157-169
  Knowledge management in a radioactive waste management environment requires specifically defined processes and a framework that must be organised to support the planning recording,

dissemination and transfer of information (collectively 'management'). Knowledge management in radioactive waste management operations (and their regulation) is primarily concerned with ensuring that present and future generation of planners, decision makers and operators have access to appropriate sources of information and that the knowledge created can be efficiently and accurately disseminated and transferred. This must be done in such a way that key personnel are equipped with the necessary skills and competencies to understand and use the knowledge. The ultimate concern must be to support the long-term safe, efficient and cost effective management of the radioactive waste management facilities and their contents.
Knowledge management will also make a major contribution to the retention and retrieval of information over the long periods of time peculiar to radioactive waste management. Retention of critical staff and knowledge transfer to new staff will clearly be necessary – this may be achieved through succession planning, training, mentoring, and other knowledge transfer processes.
The report outlines the challenges in managing nuclear knowledge that are specific to radioactive waste management organisations.

- Jensen M. (1994): Informing future societies about nuclear waste repositories. – *Radwaste Magazine*, Apr 1994, v. 1(2), p. 51-61.
  [Not available online – July 2010]
  In 1990 a working group of the NKS (the Nordic nuclear safety program) was formed and given the task of established a basis for a common Nordic view of the need for information conservation for nuclear waste repositories. The Group investigated what type of information should be conserved, in what form the information should be kept, the quality of the information, and the problems of future retrieval of information, including retrieval after very long periods of time. Topics covered include 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 vs. markers, and continuing processes in society. Archive media including paper documents, microfilm, digital media, media lifetimes.

- Jensen M. (1993): *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.
  http://www.nks.org/scripts/getdocument.php?file=111010111119462
  This is the final report of the Nordic Nuclear Safety Research Project KAN -1.3, whose purpose was to establish a basis for a common Nordic view of the need for information conservation for nuclear waste repositories, by investigating the types and forms of information and problems of future retrieval of the information in the long term. The scope covers all categories of radioactive waste from low-level waste to spent fuel, focusing on information needs in the post-closure phase. The stated motivations for preserving information include helping prevent inadvertent intrusion, enabling future generations to make decisions about safety and possibly remediation, and supporting future decision making on repositories generally. The primary audience for the report includes waste management organisations and regulatory authorities. The report includes chapters on an overall approach to the problem of conservation of information, on existing repositories and information in Nordic countries, on the types of information that need to be managed, on systems for conservation and retrieval of information, and on archive media. There are appendices on archival legislation in the Nordic countries, on the general topic of problems, methods and solutions in the transmittal of information over extremely long periods of time, on optimization, on formal methods for developing expert judgments, a bibliography of case studies, and an initial suggested prioritisation for preservation of various types of existing documents. The report recommends a multi-faceted approach, including archives at regional, national and international locations complemented by markers at the site and possibly within the repository, and periodic

reviews to determine whether some records no longer need to be kept. It recommends that guidelines be established on the kinds of records to be kept and their relative importance. It also makes suggestions for further research on potential threats to repositories and the role of information systems in responding to those threats, on types of information to be stored and procedures to extract and summarise information, and on cost effectiveness of information conservation measures.

- Johansson P, Lisberg Jensen E. (2006): *Identitet och trygghet i tid och rum – kulturteoretiska perspektiv på kärnavfallsfrågans existentiella dimensioner*. SKB R-06-119. Svensk Kärnbränslehantering AB (in Swedish)
  http://www.skb.se/upload/publications/pdf/R-06-119webb.pdf
  Interviews and textual analysis investigate the underlying thoughts about structures related to time and space, discussed in connection with the planned final repository for spent nuclear waste in Östhammar and Oskarshamn. Through metaphor, argument and discourse analysis that characterized the debates and texts, as well as informants' own formulations, different conceptions have appeared. A somewhat surprising result was the great unity of the material with however clear dividing lines. With regard to the perception of time, the period up to the decision to build a repository as well as the actual construction period (”societal time”) can be apprehended, but the long-term “repository time” is incalculable. Depending on the type of time envisaged, opinions differ on the responsibilities towards future generations.

- Kaplan M.F.(1986): *Mankind's future: Using the past to protect the future. Archaeology and the disposal of highly radioactive wastes*. – Interdisciplinary Science Reviews, vol. 11, no. 3, 1986, p. 257-268.
  [not available online – February 2011]
  In this review it is shown how archaeology can provide a basis for designing a segment of the disposal system – the marking of the site to minimize future human interference.

- Kaplan M.F. (1982): *Archaeological Data as a Basis for Repository Marker Desig*n. BMI/ONWI-354.
  [not available online – February 2011]
  This report presents a conceptual design for a marker system for a radioactive waste repository, based on a study of ancient man-made monuments. After a discussion of the reasoning behind marking the site, the report then describes a number of characteristics of messages to be conveyed, including message contents, location, survivability, detectability and comprehensibility. The report presents descriptions and assessments of a number of ancient man-mode monuments. Factors which contributed to the survival and understanding of these monuments are discussed, including the role of human actions in their destruction, and the importance of the existence of off-site written accounts of a monument in preserving understanding of its purpose. The report then presents a detailed description of a conceptual design for a system of markers to designate the site of a repository. The proposed system incorporates a series of monoliths to delineate the boundaries of the site, an earthwork in the form of a warning symbol, and a central structure to contain and preserve a copy of detailed written records, duplicating information that would also be archived at various off-site locations.

- Kawata T., Umeki H., Osawa H., Seo T., Tsuboya T., Tanabe H., Yoshimura K., Asano H., Ohuchi J. (2007): Knowledge management in the Japanese high-level waste disposal programme. IAEA-CN-153/1/O/01. – *International conference on knowledge management in nuclear facilities*, 18-21 June 2007. IAEA, Vienna.
  http://www.iaea.org/inisnkm/nkm/documents/nkmCon2007/fulltext/FP/IAEA-CN-153-1-O-01fp.pdf
  Planning and implementing disposal of high-level radioactive waste (HLW) is a multidisciplinary field. A wide range of relevant knowledge is needed to develop an associated safety case. Here, the

term “knowledge” encompasses all of the science and technology (implicitly including social science, economics, etc.) which underpins a repository project. Knowledge management covers all aspects of the development, integration, quality assurance, communication and maintenance/archiving of such knowledge - including data, information, understanding and experience. In order to ensure that required knowledge is accessible to all stakeholders, including the implementer, the regulator, political decision-makers and the general public and that gaps can be identified and prioritised, it is important that knowledge bases are structured in a clear and logical manner. This paper describes the current status of knowledge management activities in the Japanese HLW disposal programme and provides a perspective on some of the developments in this field planned for the future.

- Kazutoshi S., Hajime T., Jin Ohuchi, Takao Tsuboya (2003): *Record preservation study on geological disposal: Significance and technical feasibility*. RWMC Technical Report RWMC-TRE-03001. Radioactive Waste Management Center RWMC, Tokyo.
  http://www.rwmc.or.jp/library/pdf/RWMC-TRE-03001.pdf
  This report summarizes the results of a study carried out by the Radioactive Waste Management Funding and Research Center (RWMC) in Japan on record preservation as a component of institutional control measures for radioactive waste repositories. The study was intended to provide information to waste management and government organisations to help them formulate record preservation programs, with a primary underlying goal of improving public confidence in geological disposal. The objectives of record preservation were given as prevention of inadvertent intrusion and support for future decision making. The scope includes not only detailed records that might be preserved for decades to centuries, but also information that might be preserved for longer periods of time through the use of markers and monuments. In investigating possible methods for record preservation, five models for the development of future societies were postulated, ranging from continuous development and advancement from the present to complete disruption and a future society that had no continuity with present society. In order to respond to this range of possibilities, the study recommended two parallel approaches: a “relay system”, in which records are transmitted to future generations through institutions such as archives, and a “permanent system” based on durable markers and monuments. Basic requirements for both methods were formulated, and a conceptual design for a marker system was presented. The report describes an experimental study into the durability of engraved messages on durable media and concluded that engraving on silicon carbide showed promise as a long-term recording medium. The report includes an appendix describing historical and archaeological examples of both record preservation and physical media and artefacts, and international studies related to preservation of information on radioactive waste repositories.

- Kliewer G. (1992): The 10,000-Year Warning. - *The Futurist* 26(5), 17- (3 pages). Washington.
  [not available online]
  WIPP marker system.

- Krupar J. (2007): Burying Atomic History: The Mound Builders of Fernald and Weldon Spring. - *The Public Historian*, 29(1), 31-58.
  [not available online]
  The Fernald, Ohio and Weldon Spring, Missouri uranium refinery sites performed critical functions in the nation’s nuclear weapons manufacturing complex during the Cold War. Now, the U.S. Department of Energy has created two radioactive tombs on the former grounds of these industrial centers. These mounds may be viewed as unofficial monuments to the billions spent building and maintaining the country’s atomic arsenal. Radioactive contamination precludes the adaptive reuse of Fernald and Weldon Spring. Yet these two sites reside in counties that continue to experience steady population growth. The present and future generations need to be informed

about the activities conducted at the sites for health, environmental, and educational reasons. Policy choices made by federal government officials concerning Weldon Spring and Fernald indicate a pattern shift from disclosure/preservation to exclusion/destruction by 2005. [Abstract by author]

- LaPorte T., Keller A. (1996): Assuring Institutional Constancy: Requisite for Managing Long-Lived Hazards. - *Public Administration Review*, 56(6), 535-544.
  [not available online]

  What role do demands for constancy play in the operations of public agencies? Institutional constancy of agencies and firms is discussed as a concept and an increasingly important political requirement for the operation of hazardous systems in the United States. Situations that increase demands for it are outlined and a basis for analysis and improving constancy is proposed. [Abstract by author]

- Lomberg J., Hora S. C. (1997): Very long term communication intelligence. The case of markers for nuclear waste sites. – *Technological Forecasting and Social Change*, vol. 56, n° 2, p. 171-188.
  [not at Nagra Library, available online from ScienceDirect]

  Two interdisciplinary teams have addressed the issues of physical durability and cognitive intelligibility of markers for a U.S. government site in New Mexico. Preliminary design criteria have determined which materials are best suited to constitute markers of different sizes and shapes. A variety of linguistic, symbolic, and pictographic approaches to content have been suggested. Additional study and testing of both materials and messages is required. International standardization of marker strategies is extremely desirable.

- Makino H.; Hioki K.; Osawa H.; Semba T., Umeki H. (2012): A Challenge on Development of an Advanced Knowledge Management System (KMS) for Radioactive Waste Disposal: Moving from Theory to Practice. – In: *New Research on Knowledge Management Technology*, Huei Tse Hou (Ed.), InTech.
  http://cdn.intechopen.com/pdfs/29146/InTech-A_challenge_on_development_of_an_advanced_knowledge_management_system_kms_for_radioactive_waste_disposal_moving_from_theory_to_practice.pdf

  The exponential growth in the knowledge base for radioactive waste management is a cause for concern in many national programmes. In Japan, this problem is exacerbated by a volunteering approach to siting of a deep geological repository, which requires particular flexibility in the tailoring of site characterisation plans, repository concepts and associated Performance Assessments (PAs). Recognition of this situation led, in 2005, to initiation by Japan Atomic Energy Agency (JAEA) of an ambitious project to develop an advanced Knowledge Management System (KMS) aimed to facilitate its role as the supplier of background R&D support to both regulators and implementers of geological disposal. The paper reviews progress to date in this work, with emphasis on tailoring of existing Knowledge Engineering tools and methods to radioactive waste management requirements, and outline future developments and challenges.

- Mann W.B. (1986): Identification of nuclear-waste sites over ten millennia. *Nuclear and chemical waste management* 6, 95-100.
  [not available online]

- Marshall A. (2008): Leaving messages about our radioactive waste for future generations. – In Lattefer A.P. (ed.), *Nuclear Waste Research: Siting, Technology and Treatment*. Nova Science Publishers, 37-45.
  [not available online, not at Nagra]

- Marvy A., Lioure A., Heriard-Dubreuil G., Gadbois S., Schneider T., Schieber C. (2003): A look at new key performance criteria that could most affect the safety of long term storage of nuclear waste: A case study commissioned by CEA. Paper IAEA-CN-90/11.- *International conference on Issues and trends in radioactive waste management: Vienna, 9-13 December 2002*. IAEA, Vienna, p. 47-51. Available through INIS: http://inisdb.iaea.org/inis/php/download.php?s=p&rn=34016251

  As part of the work scope set in the French law on high level long lived waste R&D passed in 1991, CEA conducted research work to establish the scientific basis and assess the feasibility of long term storage as an option for the safe management of nuclear waste for periods as long as a few centuries. This goal was a significant departure from current industrial practice where storage facilities are usually built to last only a few decades. The case study looks into several past and actual human enterprises conducted over significant periods of time – one dating back to the end of the 18th century – and identified off the nuclear field. As a result the study group obtained a set of performance criteria relating to issues like responsibility, securing funds, legal and legislative implications, economic sustainable development, all being areas which are not traditionally considered when technical studies are conducted.

- Massart C. (2004): How plural interests, values and knowledge could be translated into a concrete radwaste disposal project design: an artist's vision. – *Dealing with interests, values and knowledge in managing risk: Workshop proceedings*, Brussels, Belgium 18-21 November 2003. OECD/NEA, Paris, 117-121.
  [Not available online – can be ordered from the OECD bookshop]

  Professor and Artist, C. Massart operates from the understanding that a proper role for art in radioactive waste management projects can help change the view of waste disposal by stakeholders and the broader public. She has investigated both the artistic aspects of waste management facilities themselves as well as artistic visions of themes associated with radioactive waste. For the past ten years, Professor Massart has been working on a project titled, "An archived site for alpha, beta, gamma." She has explored three separate topics in which using art as a vehicle for communication offers an alternative and perhaps improved method for communicating over the more "traditional" verbal and written communications. The first was to portray radioactive decay not by measurements or comparisons to other risks, but to use the gradual lightening of colours to depict the gradual and natural decay of radioactivity with time in an artistic piece. Second, she demonstrated the possibilities for art to help maintain archives for the future, a key knowledge preservation activity for a programme that will span generations. Third, she showed the possibilities for art to influence markers that would ultimately be placed at waste management sites, preserving the continuity of knowledge regarding such sites.

- Maxeiner H. (2002): "Dokumentationssystem für radioaktive Materialien der Schweiz = Swiss documentation system for radioactive materials".- *Praxis des Strahlenschutzes: Messen, Modellieren, Dokumentieren: 34. Jahrestagung des Fachverbandes für Strahlenschutz e.V., Kloster Seon, 21.-25. April 2002*. Fachverband für Strahlenschutz, Jülich.
  [available from Nagra upon request]

  This paper describes the Swiss "Information System for Radioactive Materials (ISRAM)", that documents all relevant work steps, from planning of conditioning procedures through transport to interim storage, as well as the results of characterisation programs. The spectrum of wastes and materials covered by the system ranges from operational waste from the nuclear power plants (including activated reactor internals) through wastes from medicine, industry and research to vitrified waste from reprocessing and spent fuel.

- McCarthy G. (2005): Report on the International Atomic Energy Agency 'Draft Safety Report on Preservation and Transfer to Future Generations of Information Important to the Safety of Waste Disposal Facilities'. - *Cooperation on Archives of Science in Europe. Newsletter,* 11, June 2005.

http://www.sac.cat/ficha_notes.php?sitelang=ca&idnoti=366&pw=gavan

- Merz E. (1985): Endlagerung: Übermittlung der Kunde vom Atommüll in ferne Zukunft. – *Atomwirtschaft, Atomtechnik*, May 1985, p. 234.
  [not available online – February 2011]
  Critical review of Sebeok (1984) and Tannenbaum (1984).

- Mey J. (1995): The last Canterbury Tale: Artificial intelligence in the fifth millennium. Prague Lingustic Circle, Vol. I, 1995, p. 281ff.
  Partially reproduced in http://books.google.ch/books?id=5jS-V5lKcVQC&pg=PA285&lpg=PA285&dq=Riddley+Walker+atomic+priesthood&source=bl&ots=ZgT0pM_vxf&sig=U5C1Pv54v9bKZDZU3KB_idJkKoA&hl=de&sa=X&ei=vSVMUZjZEozDtAbs4YCoCg&sqi=2&ved=0CFIQ6AEwAw#v=onepage&q=Riddley%20Walker%20atomic%20priesthood&f=false
  The paper discusses both Posner 1990 (see below) and the science fiction novel "Riddley Walker" by Russel Hoban. It includes in particular a reflection on the perennity of the language and on the concept of "atomic priesthood".

- Moser C., Stauffacher M., Krütli P., Scholz R.W. (2012): The crucial role of nomothetic and idiographic conceptions of time: Interdisciplinary collaboration in nuclear waste management. – *Risk Analysis* 32 / 1, 138-154.
  [not available online, June 2012]
  This paper sums up the results of interviews with scientists from various disciplines, on the subject of the perception of time. Knowledge preservation is only marginally mentioned.

- National Research Council, Committee on the Remediation of Buried and Tank Wastes, Board on Radioactive Waste Management (2000): *Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Sites*.
  [can be downloaded from https://download.nap.edu/catalog.php?record_id=9949)
  See in particular Chapter 5, Stewardship activities. This document deals in particular with the collection and dissemination of information related to the monitoring and remediation phase of residually contaminated sites. It also lists problems that can arise in conducting long-term stewardship activities.

- National Security Technologies ST (2007): *Passive Barriers to Inadvertent Human Intrusion for Use at the Nevada Test Site*. DOE/NV/25946-206. NST, Las Vegas.
  http://www.osti.gov/bridge/servlets/purl/917998-fysXWd/917998.pdf
  This report documents the results of a study conducted to identify types of engineered passive barriers that could deter future intrusion into buried low-level radioactive waste at the Nevada Test Site, in particular intrusion by drilling water wells. The study considered drilling technology, many natural and man-made materials, and both underground and above-ground barriers. Based on considerations of cost and effectiveness, the study recommended three types of barrier for use at the Nevada Test Site: and underground layer of rubble, an underground layer of rubber tires, and an above-ground barrier mound.

- Nelson R.S. & Olin M. (eds.) (2003): *Monuments and memory, made and unmade*. University of Chicago Press. Chicago.
  [not available online]
  How do some monuments become so socially powerful that people seek to destroy them? After ignoring monuments for years, why must we now commemorate public trauma, but not triumph, with a monument? To explore these and other questions, Robert S. Nelson and Margaret Olin

assembled essays from leading scholars about how monuments have functioned throughout the world and how globalization has challenged Western notions of the "monument." Examining how monuments preserve memory, these essays demonstrate how phenomena as diverse as ancient drum towers in China and ritual whale-killings in the Pacific Northwest serve to represent and negotiate time [summary: Internet]
See in particular Bryan-Wilson J.: Building a Marker of Nuclear Warning, pp. 183-204.

- Nolin J. (1993): *Communicating with the future: implications for nuclear waste disposal*.- Futures, 1993, Bd. 25, Nr. 7, S. 778-791.
  [available through ScienceDirect]
  Can we transmit a message about nuclear waste - warnings or instructions - to be received thousands of years from now? Can we ensure that crucial information will be available and intelligible at a critical moment? This article combines the debate generated by these questions with a discussion on knowledge in context. Two perspectives are introduced: in one it is claimed that knowledge can survive through different contexts; in the other it is argued that the importance of context is such that time will render our messages incomprehensible. These perspectives are linked to two alternatives, both discussed within the context of US and Nordic nuclear waste management. One is the 'long-term concept' of a marker or an archive that conserves the information once and for all. The other is a 'short-term' concept that suggests a continuous recoding of the messages in new contexts in order to 'keep it alive'. Finally, a combination of these alternatives is discussed.

- Nora P. (1989): Between Memory and History: Les Lieux de Mémoire. – *Representations* 26 (Spring 1989), 7-25.
  [not available online]

- Nuclear Decommissioning Authority, Upshall I. (2010): *Requirements Framework for Managing Information Relating to Radioactive Waste on Nuclear Decommissioning Authority Sites*, Document No. 13006659. NDA, Didcot (UK).
  [not available online, available from the NDA on request]
  This document was prepared by the NDA for use by the NDA, its contractors (Site Licensing Companies), and other entities in the UK that envisage using NDA facilities for storage or disposal of radioactive waste. It provides a framework for information management systems to comply with corporate policies, regulatory requirements and regulatory guidance. The document sets out a series of 27 requirements for the management of records and information relating to radioactive waste. Its main focus is on ILW, although it is expected that it would be applicable, with modifications, to LLW and HLW. Each of the 27 requirements is accompanied by a description of the reasons for its adoption and guidance on its implementation. The majority of the discussion is related to records management prior to disposal, but there are also brief discussions of information management needs during and after disposal. The requirements cover a range of topics including policy, roles and responsibilities, quality management, information risk management, metadata, access, media, storage, review processes, minimum information requirements, and the transfer of information management responsibilities between organisations. There are sections devoted specifically to the management of existing (legacy) records as well as to the creation and management of information related to newly-generated waste. The document includes appendices on recording media and indicative lists of minimum information data sets as well as of contextual information (metadata).

- OECD Nuclear Energy Agency (2011-2014): Project on “Long-term preservation of records, knowledge and memory across generations”

➔ For a full list of publications see the section "On-going initiatives / Projects" at the end of this document. Current versions of the documents can be obtained from the NEA.

- OECD Nuclear Energy Agency (2014): Preservation of Records, Knowledge and Memory across Generations (RK&M): *Markers – Reflections on Intergenerational Warnings in the Form of Japanese Tsunami Stones*. OECD/NEA, Paris. http://www.oecd-nea.org/rwm/docs/2014/rwm-r2014-4.pdf

  This report seeks to develop the understanding of the potential effectiveness of makers drawing from the study of the role that stone markers played in Japan during the Tōhoku tsunami event of 2011. There are hundreds such markers placed at various epochs on Japan's north-eastern coast to warn future generations about the dangers of tsunamis [Abstract by author]

- OECD Nuclear Energy Agency (2010): *More than just concrete realities: The symbolic dimension of radioactive waste management.* OECD/NEA, Paris. http://www.oecd-nea.org/rwm/reports/2010/nea6869-symbolic.pdf

  This report presents the results of a topical session held by the NEA's Forum on Stakeholder Confidence (FSC) in 2008 on the theme of the symbolic dimension in communicating about radioactive waste management facilities. It explores the symbolic dimension of radioactive waste as a whole, as well as of key waste management-related concepts such as safety and risk, land and landscape, and storage and disposal. It also addresses the role of framing of arguments and communications and the role this framing may play in how statements and communications are interpreted. The reports' conclusions emphasise the need for building awareness of the importance in shaping dialogue of symbols rooted in social convention and cultural tradition.

- OECD Nuclear Energy Agency (2010): R*adioactive waste repositories and host regions: Envisaging the future together*. Synthesis of the FSC national workshop and community visit Bar-le-Duc, France 7-9 April 2009. OECD/NEA, Paris. http://www.oecd-nea.org/rwm/reports/2010/nea6925-repositories-host-regions.pdf

  This report is a synthesis or proceedings of a workshop held at Bar-le-Duc, France by the NEA's Forum on Stakeholder Confidence (FSC) in 2009. The workshop focused on the implementation of France's high-level and long-lived intermediate-level waste management programme in the region near Bar-le-Duc. Workshop sessions addressed the French historical and legislative context, local public information, reversibility expectations and motivations, economic support and regional development, and environmental monitoring and the issue of memory, and also included a site visit to the underground laboratory at Bure. The discussion on memory noted that active memorialisation will depend on maintaining exchanges with the local public during and after implementation. The report also includes an international perspective on the workshop from the point of view of the NEA Secretariat. This perspective notes the importance of concerns raised over the long-term governance of the facility, including fears that a future national government might delegate responsibility for site monitoring and management to local governments that might not have the resources or capabilities to meet these requirements.

- OECD Nuclear Energy Agency (2007): *Fostering a durable relationship between a waste management facility and its host community. Adding value through design and process*. OECD/NEA, Paris. http://www.oecd-nea.org/rwm/reports/2007/nea6176-fostering.pdf

  This report was prepared by the NEA's Forum on Stakeholder Confidence (FSC) in order to explore ways to achieve sustainability, i.e. societal durability, in planning and implementing radioactive waste management facilities. The target audience includes both potential host communities and national radioactive waste management programmes. The scope is not limited to any particular type of waste or method of disposal. The report does not address compensation, incentives or spin-offs, but rather focuses on the ways in which a facility might add value and

improve the prospects for quality of life in the surrounding community in both the short and long term. The report summarises arguments in favour of developing a sustainable relationship between a community and a radioactive waste management facility through added cultural and amenity value. It identifies design considerations that may help facilities and sites fit into their community in an acceptable and sustainable manner. The design features considered include functional aspects such as multi-functionality, adaptability and flexibility; cultural aspects such as distinctiveness, aesthetic quality, understandability and memorialisation (heritage and markers); and physical aspects such as integration, amenity and accessibility. The report also addresses ways in which the planning, decision-making and implementation processes can provide added value for the community. The discussion is illustrated by examples gathered from several waste management programmes as well as direct input from stakeholders representing communities where facilities have been located or proposed.

- OECD Nuclear Energy Agency (1995): *Future human actions at disposal sites: safety assessment of radioactive waste repositories = Les actions humaines futures sur les sites d'évacuation*. OECD/NEA, Paris.
  http://www.oecd-nea.org/rwm/reports/1995/nea6431-human-actions.pdf
  This document summarizes the work of the NEA Working Group on Assessment of Future Actions in the 1989-1995 time frame. The Working Group reviewed work on the topic that had been done in member nations and internationally, identified issues deserving of further consideration, and made recommendations on generic approaches and further studies that could be undertaken. The scope of the work was limited to deep disposal of long-lived high-level wastes, and to potential inadvertent human actions post-closure with the potential to impact repository safety. The Working Group considered approaches to consequence analysis, measures to reduce the likelihood and/or consequences of intrusion, including preservation of records, knowledge and memory, and made recommendations on future international activities. Countermeasures to intrusion that were considered included siting and isolation considerations, design measures to reduce consequences of intrusion, conservation of information, physical markers, and physical barriers to intrusion. The group reviewed and summarized past assessments, including in particular those described in the KAN-1.3 report and the work on markers carried out in support of WIPP. It developed a set of scenario-building elements for development of future human action scenarios in safety assessment, and made recommendations for future international work, including development of an international archive of radioactive waste repositories and further work on markers.

- Ohuchi J., Torata S., Tsuboya T. (2006): Robust record preservation system on geological repository. IAEA-CN-123/03/O/02. – *International conference: Managing nuclear knowledge: Strategies, information management and human resource development*, Saclay, 2004. IAEA, Vienna.
  http://www.iaea.org/km/cnkm/papers/ohuchi.pdf
  Although we cannot predict the future of society we need robust and redundant systems for preserving records that should be accessible, retrievable and understandable for future generations. The balance of active and passive system was considered. It was also found that long-term record preservation may be useful to communicate with the current generation, as a “meta-signal”, in addition to aiming at warning and allowing decision-making. Finally, the laser-engraving technology on silicon carbide was presented as an alternative to paper and maybe to microfilm. Another case study concerned the future generations’ accessibility to the preserved records.

- Ohuchi J., Sugiyama K., Asano H., Tsuboya T. (2003): Conceptual system of robust record preservation on geological disposal.- *Process through cooperation: Proceedings of the 10th International high-level radioactive waste management conference*: March 30 - April 2, 2003, Las Vegas, Nevada, p. 1227-1234.
  [not available online – February 2011]

See above, Ohuchi et al. (2004)

- Pasqualetti M.J. (1997): Landscape Permanence and Nuclear Warnings. *Geographical Review* 87(1), 73-91.
  [not available online]
  From the perspective of a human lifetime, the hazards of some nuclear wastes are permanent, so the warnings we place at contaminated nuclear sites must be permanent too. I address questions of how best to provide one hundred centuries of public warning at the first facility for permanent disposal, the Waste Isolation Pilot Plant in New Mexico. Scenarios of intrusion developed to guide the design of warning markers predicted that most of the changes in the area will be social and cultural. Because blatant and permanent markers will increase, not reduce, the probability of inadvertent intrusion, the most appropriate warning is a "landscape of illusion." Such a landscape needs not permanent surface markers but underground warning devices beneath a soft surface marker. No warning can guarantee deterrence for 10,000 years, however. [*Abstract by author*]

- Pastina B. (2004): Implementing long-term stewardship: a national challenge. - *IICER Workshop "Long-Term Performance Monitoring of Metals and Radionuclides in the Subsurface: Strategies, Tools and Case Studies"*, April 21, 2004.
  http://www.cistems.fsu.edu/PDF/pastina.pdf
  The purpose of this paper is to report on a National Academies workshop on long-term stewardship, held on March 16, 2004. The workshop was organized as a result of growing concerns among certain federal agencies and stakeholder communities over the environmental liabilities left behind at contaminated sites after cleanup ends. Long-term stewardship is a national challenge with thousands of sites with residual radioactive or chemical contamination requiring long-term stewardship. Views on cleanup end states differ significantly between the "remediator" and the "steward;" there appears to be significant challenges for periodic reviews of selected remedies, and there might be a need for policy changes in long-term stewardship regulations; also, different sites have different long-term stewardship needs but there are lessons to share. There appears to be a need for advice on the use of science and technology during cleanup and stewardship to reduce environmental liabilities.

- Paztor S.B., Hora S.C. (1994): Lessons from the Vatican archives for repository recordkeeping.- *Radwaste Magazine*, 1994, Bd. 1, Nr. 3, p. 39-47. (This article is excerpted from a longer report by the same authors, "The Vatican Archives: A study of its history and administration", NKS/KANN 1.3(91)6, available from the Swedish Radiation Protection Institute).
  [not available online – February 2011]
  The Vatican Archives, one of the world's oldest document repositories, contains documents dating back to the ninth century and continuous documentation of the administration of the Roman Catholic Church from the twelfth century. By assessing the strengths (private collection in a politically neutral city-state) and weaknesses (inadequate protection from environmental threats, lack of adequate access system, rather haphazard policy regarding outside access to documents) of the Vatican Archives, valuable lessons can be learned for the design and management of an archival system for nuclear waste records.

- Pescatore C., Mays C. (2009): Records, Markers and People: For the Safe Disposal of Radioactive Waste. – In: *VALDOR 2009: Values in Decisions on Risk, Stockholm (Sweden) 8-11 Jun 2009: Proceedings*.
  Available through INIS: http://inisdb.iaea.org/inis/php/download.php?s=p&rn=41021980
  The timescales over which the hazard exists from radioactive waste (as well as from other wastes) are much longer than just a few thousands of years, and it must be accepted that the current generation's capacity to ensure continued integrity of the disposal facility cannot be projected

indefinitely into the future, but rather diminishes with time. There is therefore the need to conceptualise a 'rolling future' in which each generation takes responsibility to ensure continuity and safety for the succeeding several generations, including a need for flexibility and adaptability to circumstances as they change. The issue of archives and markers that last as long as possible (the technological approach) continues to be a topical one. However, physical markers and archives may be complemented by - or integrated within - a cultural tradition that could be sustained over time starting with the planning of a repository and continuing through its implementation and beyond its closure. Because a radioactive waste management repository and site will be a permanent presence in a host community for a very long time, a fruitful, positive relationship must be established with tose residing there, now and in the future. The challenge is to design and implement a facility (with its surroundings) that is not only accepted, but in fact becomes a part of the fabric of local life.

- Pescatore C., Mays C. (2008): Geological disposal of radioactive waste: records, markers and people: An integration challenge to be met over millennia. – *NEA News* no. 26, 2008, 26-30. http://www.oecd-nea.org/pub/newsletter/2008/Geological%20Disposal.pdf
  [See above, Pescatore & Mays 2009]

- Posner R. (ed.) (1990): *Warnung an die ferne Zukunft : Atommüll als Kommunikationsproblem* [Warnings to the far future. Radioactive wastes as a communications problem]. Raben Streifzüge. Raben Verlag, München, 1990.
  http://www.semiotik.tu-berlin.de/fileadmin/fg150/Posner_1990-Mitteilungen_an_die_ferne_Zukunft_ONLINE.pdf
  Inquiries were launched in the USA, in Poland, France, Hungary, Brazil, and the Federal Republic of Gemany to find semiotic solutions to problems arising from the communication of radioactive waste locations and dangers to posteriority. How can information be communicated over a period of 10000 years? What has been communicated to us from the past 10000 years? It seems to be sure that neither natural nor artificial barriers nor remnants (e.g. skeletons) or sources (today's communication), but only explicit messages will keep intelligent creatures from intrusion into radioactive waste depositories. Among the subjects dealt with are: Pandora's box and how to prevent its opening; mathematical coding on living sign matter; living detectors and complementary signs: “ray cat”, “broken eye”, and nuclear sirens; the three-chamber system: a way to the democratic organization of collective knowledge and conscience which can survive millennia.
  Includes in particular:
  - Roland Posner: Mitteilungen an die ferne Zukunft. Hintergrund, Anlass, Problemstellung und Resultate einer Umfrage
  - Thomas A. Sebeok: Die Büchse der Pandora und ihre Sicherung: Ein Relaissystem in der Obhut einer Atompriesterschaft
  - Stanislaw Lem: Mathematische Kodierung auf lebendem Trägermaterial
  - Françoise Bastide / Paolo Fabbri: Lebende Detektoren und komplementäre Zeichen: Katzen, Augen und Sirenen
  - Vilmos Voigt: Konzentrisch angeordnete Warntafeln in zunehmend neueren Sprachformen
  - Philipp Sonntag: Künstlicher Mond am Himmel und Datenbank im Keller
  - Wulf Rehder: Sicherung gegen Kodebrecher durch Randomisierung
  - Percy H. Tannenbaum: Staffelung der Informationsquellen nach Inhalt und Entfernung von den Lagerstätten
  - David B. Givens: Was wir aus der Menschheitsgeschichte lernen können
  - Marshall Blonsky: Wes Geistes Kind ist die Atomsemiotik?

  - Susanne Hauser: Problematisch sind nicht nur die Antworten, sondern bereits die Voraussetzungen

- Powell J., Griffiths G., Walpole S., Lutz M. (2009): The Fernald Preserve Visitors Center: The Fernald Experience - Revealing, Engaging, and Preserving. - *WM2009 Conference, March 1–5, 2009, Phoenix, Arizona*.
  http://www.wmsym.org/archives/2009/pdfs/9426.pdf
  The U.S. Department of Energy (DOE) Office of Legacy Management's public involvement activities at the Fernald, Ohio, site include continued communication about groundwater remediation, the management of legacy waste, and the future of the Fernald site. The completion of the Fernald Preserve Visitors Center, in August 2008, ensures that information continues to be readily available and effectively communicated to the public. A primary goal of the Visitors Center is to function as an informational and educational center within the surrounding community, with the information available at the Visitors Center serving as an institutional control. By offering information on a variety of topics, from the site's history to its current condition, the Visitors Center increases public awareness and helps prevent unsafe disturbances to and uses of the site. The Office of Legacy Management maintains and operates the Visitors Center, continues to solicit stakeholder opinion, and will periodically reevaluate the use of the Visitors Center and its programming. [Abstract by author]

- Schiesswohl S., Bahrke C., Deyo Y., Uhlmeyer T. (2007): Long-Term Stewardship: Institutional Controls on Department of Energy Sites. – P*roceedings of Waste Management Symposium WM07, February 25 - March 1, 2007*: Global Accomplishments in Environmental and Radioactive Waste Management: Education and opportunity for the next generation of waste management professionals. American Nuclear Society, La Grange Park.
  http://www.wmsym.org/archives/2007/pdfs/7462.pdf
  The U.S. Department of Energy (DOE) has managed the Long Term Stewardship and Maintenance activities at DOE sites since 1988. DOE's Office of Legacy Management (LM) was established in December 2003, and its specific mission is to manage the DOE's post-closure responsibilities and ensure the future protection of human health and the environment. LM has control and custody for legacy land, structures, and facilities and is responsible for maintaining them at levels suitable for their long-term use. LM uses a wide range of institutional controls (ICs) as part of efforts to appropriately limit access to, or uses of, land, facilities and other real and personal property assets; protect the environment; maintain the physical safety and security of DOE facilities; and prevent or limit inadvertent human and environmental exposure to residual contaminants and other hazards. DOE is using a 'defense in depth' strategy which uses multiple mechanisms to provide 'layering' for additional durability and protectiveness: Proprietary controls, Governmental controls, Enforcement and permit tools with IC components, Informational devices. An additional practice that supports ICs at LM sites entails the use of engineered controls, such as fences, gates, access controls, etc.

- Schneider T., Schieber C., Lavelle S. (eds.) (2006): *Long term governance for radioactive waste management*, Final report of COWAM2, WP4. COWAM2-D4-12 CEPN - R – 301. December 2006.
  http://www.cowam.com/IMG/pdf_cowam2_WP4.pdf
  This is the final report of the COWAM2 Working Party 4 (WP4). COWAM2 (Community Waste Management) was a cooperative research programme supported by the European Community in 2004-2006 to investigate governance processes for radioactive waste management. Participation was broadly based, including representation from local communities, elected representatives, NGOs, social and natural scientists, waste management organisations, regulators and waste producers. The aim of WP4 was to propose guidelines in order to better address long term issues in decision-making processes and start long term governance. Investigating the topics of long term, future generations and governance, the report concludes that in order to bridge the gap between

technically relevant and socially meaningful time scales, the most appropriate approach is one of continued transfers of knowledge, safety heritage and responsibility from each generation to the next. The working group investigated ethical issues and proposed ethical criteria in the areas of responsibility, justice and democracy. In order to best promote and achieve continuity and sustainability of surveillance, the group recommended the creation of centres of competence and integration of the radioactive waste management facility and its surveillance in a local/regional socio-economic development. Financing schemes were studied, and the importance of transparency was emphasised. The guidelines prepared by the group comprise a series of technical, institutional, financial, societal and ethical considerations to be taken into account in the establishment and continued development of long-term governance processes by stakeholders at local, national and international levels.

- Schröder J., Pescatore C. (2012): Preservation of Records, Knowledge and Memory across Generations. An emerging multidisciplinary work area and an NEA project. – *WM2012 Conference, February 26 – March 1, 2012, Phoenix, Arizona, USA*.
  [not available online, June 2012]

- Sebeok Th. A. (1984): *Communication measures to bridge ten millenia*. BMI/ONWI-532.
  [not available online – February 2011]
  This report describes a semiotic analysis of the problem of devising a method of warning future generations of the presence of hazards at the site of a radioactive waste repository. It describes some basic principles of semiotics, or the study of messages conveyed by any means, whether linguistic or symbolic. It describes various types of messages and communications channels. Some problems with using images for communicating, as well as issues related to decipherment of written records, are described. The report recommends that a "relay system" of passing information from one generation to the next be initiated incorporating folkloristic or heritage elements and a built-in enforcement system intended to ensure that future generations continue the relay process ("atomic priesthood"). A high degree of redundancy and diversity of components, both linguistic and symbolic, is also recommended.

- Sheats D.G. (1992): Records Management in support of the licensing process for the high level radioactive waste facility. – *Proceedings of High Level Radioactive Waste Management*, Volume 1, La Grange Park, IL (United States). American Nuclear Society, p. 2083-2087.
  [not available online – February 2011]
  This paper reports that the Yucca Mountain project is imposing a unique set of requirements of the Records Management (RM) Program. Not only must RM function in the traditional role as archivist, but, in relationship to the Licensing Support System (LSS), perform the function of Information Manager. As information Manager, it becomes vitally important that RM fully understand the Licensing Process and the regulatory requirement imposed by the process.

- Sigurdson B.E., Snider R.C., Bilokury M.R. (2003): Issues and considerations on the development of an institutional control policy for uranium mines within Northern Saskatchewan. Paper IAEA-CN-90/60. – *International conference on Issues and trends in radioactive waste management*: Vienna, 9-13 December 2002: Contributed papers. IAEA, Vienna, p. 308-313.
  [not available online – February 2010]
  There is currently no clear provincial policy with respect to a proponent's application for release from a reclaimed and decommissioned site, and the resulting provincial responsibility for the long-term management and maintenance of the site once a release has been granted. Another policy issue has been identified with respect to the long-term institutional control of previously abandoned uranium mine sites.

- Sprenger F. (2007): *Atommüllendlager: Medien, Zeit und Raum eines Kommunikationsproblems*. Ruhr-Universität Bochum, Fakultät for Philologie.
  [not available online]
  General overview on communication issues over long timescales, focussing in particular on information theory, media and memory.

- Sumerling T. (2005): *Control, Loss of Control, Causes, Putative Scenarios and Option Performance: Support to CoRWM – Task TS108/4*. SAM-J114-TN1, Version 2, 7 November 2005.
  [unpublished, available from Nagra upon request]
  Review of existing literature regarding loss of control.

- Svensk Kärnbränslehantering AB (2010): *Handling of future human actions in the safety assessment SR-Site*. Technical Report TR 10-53. SKB, Stockholm.
  http://www.skb.se/upload/publications/pdf/TR-10-53webb.pdf
  This document is a supporting document to the safety assessment for a KBS-3 repository, and documents the scenarios and assumptions about future human actions that were used in that safety assessment. The purpose of the report is to document general considerations, assessment methodology, aspects considered and the selection of scenarios for future human actions after closure, with a focus on the longer time scale after institutional controls are assumed to be no longer effective. The report describes the strategy used by SKB to deal with future human actions. It then discusses a variety of prospective future actions with the potential to impact on the safety of the repository, i.e. on the health and safety of persons living in the vicinity. This is followed by a discussion of conceivable societal contexts for these future actions, with a view towards assessment of the plausibility of such actions. Knowledge, both at the general (hazards and management of radioactive waste) and specific (location and contents of the repository) levels, is recognized as a key issue. The discussion concludes that there can be no guarantee of preservation of knowledge, regardless of whether society evolves in a positive or negative way, and therefore future human action scenarios are credible events to be considered in the safety assessment. Several scenarios are selected and described and their potential safety consequences are evaluated.

- TallBear K. (2001): Tribal social & cultural institutions for long-term stewardship of hazardous sites. Presented at the National Academy of Sciences National Research Council Board on Radioactive Waste Management, Washington, D.C., 3 April 2001 and at the Roundtable on tribal issues and opportunities related to the long term stewardship of contaminated federal facilities, Lakewood, Colorado, 14-15 March 2001.
  http://www.iiirm.org/publications/Articles%20Reports%20Papers/Environmental%20Protection/socialcul.pdf

- Tannenbaum P.H. (1984): *Communication Across 300 Generations: Deterring Human Interference with Waste Deposit Sites*. BMI/ONWI-535.
  [not available online – February 2011]
  This report presents a social psychologist's review of issues related to the use of symbolic elements in markers intended to communicate the presence of a radioactive waste repository to future generations in order to deter inadvertent intrusion. It describes findings in a number of areas, including the role of message location, message content, and in particular various aspects affecting sensory reception, attention, perception and cognition, and memory. The trefoil and related symbols are investigated. The report makes suggestions on research that could/should be carried out to determine which kinds of symbols are most likely to be effective irrespective, to the extent feasible, of language and culture.

- Taylor B.C., Kinsella W.J., Depoe S.P. (eds) (2007): Nuclear Legacies: Communication, Controversy, and the U.S. Nuclear Weapons Complex. Lexington Books.

  In part 2, which emphasises organisational aspects of nuclear weapons production, Jason Krupar and Stephen Depoe compare historical preservation efforts at the Nevada test site near Las Vegas, the uranium refinery in Fernald, and the plutonium trigger factory at Rocky Flats near Denver. Only the Atomic Testing Museum in Las Vegas managed to attract federal monies, but it was immediately criticized as presenting a revisionist version of cold war history. By contrast, the Rocky Flats Virtual Exhibit, an online museum created without federal funding, presents an alternative, and much more critical, account of the nuclear age. Laura A. McNamara's essay focuses on attempts to preserve knowledge about designing reliable nuclear weapons since the 1992 testing moratorium. On the basis of fieldwork at Los Alamos, she explores how nuclear weapons designers constitute, maintain, and modify their community of knowing.

- Theis S. (2002) : Die Dokumentation radioaktiver Abfälle im Lichte einer mehrere Jahrzehnte andauernden Zwischenlagerung = The documentation of radioactive waste in the view of several decades of interim storage.- *Praxis des Strahlenschutzes: Messen, Modellieren, Dokumentieren: 34. Jahrestagung des Fachverbandes für Strahlenschutz e.V., Kloster Seon, 21.-25. April 2002*. Fachverband für Strahlenschutz, Jülich.
  [not available online – February 2011]

  Except for the operational documentation of the waste producer and conditioner the properties of radioactive waste packages have been described from the very beginning of their production according to the acceptance criteria of the final repository which was available at the time being. In chronological order the respective repository projects were Asse, Konrad and Morsleben. Further requirements from interim storage had not been considered as necessary. After changing the German repository policy in autumn 1998 a prolonged period of several decades without an operating national repository must be considered. Hence the operators and supervising authorities of the existing interim storage facilities formulated additional requirements especially regarding qualification of the waste containers and additional details of several chapters of the waste documentation.

- Tolan T.L. (1993): *The use of protective barriers to deter inadvertent human intrusion into a mined geologic facility for the disposal of radioactive waste: a review of previous investigations and potential concepts*. Contractor Report. SAND91-7097. Sandia National Laboratories, Albuquerque.
  [not available online – February 2011]

  This report contains a background review of information on the use of protective barriers to thwart inadvertent intrusion into a radioactive waste repository, with particular reference to the WIPP repository. The physical and geological setting in which the WIPP repository is located are described, including the potential for resource exploration and extraction nearby. The regulatory requirements and guidance related to passive institutional controls are presented. Protective barriers would form one element of a defense-in-depth system of passive institutional controls. The report presents a review of previous investigations into the subject, including a description of surface mound barriers proposed for use at near-surface waste repositories at the Hanford Site. Observations are made on the potential location and nature of possible barriers for use at a geological repository, including the potential for barriers that would make drilling of boreholes difficult.

- Tonn B.E. (2004): Integrated 1000-year planning. - *Futures* 36(1), 91-108.
  [not available online]

  This paper develops the concept of integrated 1000-year planning. The products of 1000-year planning, referred to as 1 000-year plans, are intended to deal with issues on a global scale and address the survival of humanity and the protection of the earth's environment. One thousand years

is an appropriate global planning horizon because it is long enough to unmask big picture problems that appear to be invisible to today's societies. Furthermore, this time horizon encourages the perspective that over the long-term, many problems that seem unsolvable today, and therefore receive little attention and few resources, can indeed be overcome. Topics of 1000-year plans are numerous and include: energy, land use, carbon management, oceans, biodiversity, nuclear and hazardous waste, water, human Settlements, near-earth objects, and space exploration. The argument is made that responsibilities for action by current generations to benefit future generations be based on risk assessments and risk thresholds. In the near-term, 1000-year planning must be driven by an international grassroots coalition of scientists, policy analysts, environmentalists, planners, and concerned citizens. *[Abstract by author]*

- Tonn B.E. (2001): Institutional designs for long-term stewardship of nuclear and hazardous waste sites. - *Technological Forecasting and Social Change* 68, 255–273.
  [not available online]
  This article evaluates several designs for an institution to act as the steward for legacy sites. To offer lessons learned about the characteristics of long-lasting human institutions, several that have existed for hundreds and thousands of years are reviewed, including the Dominican monastic order, the Sangha community of Buddhist monks, and universities such as those located in Oxford and Paris. Six alternative institutional designs are evaluated over a set of four evaluation criteria. It is recommended that the United States establish a new type of secular nonprofit institution, entitled The Stewardship Institution, to act as steward for the sites. This option is judged most able to focus on the mission of stewardship, meet its technical challenges, survive inevitable periods of political and economic instabilities, and meet current generation cost and implementation concems. Other institutions considered include a consolidated national stewardship organization, a religious organization, and a new state of the union called the Legacy State. *[Abstract by author]*

- Trauth K.M. (1994): WIPP marker development. - *Radwaste Magazine*, vol. 1, No. 2, April 1994, p. 46-52.
  [not available online – February 2011]
  Development of permanent, passive markers for the Waste Isolation Pilot Plant. Work carried out at Sandia National Laboratories [see also Hart 2004, Hart 2000, US DOE 2000, US DOE 1996]

- Trauth K.M., Hora S.C., Guzowski R.V. (1993): *Expert judgment on markers to deter inadvertent human intrusion into the Waste Isolation Pilot Plant*. Sandia Report SAND92-1382. Sandia National Laboratories, Albuquerque.
  http://www.wipp.energy.gov/picsprog/Test1/SAND%2092-1382.pdf
  This report describes the studies carried out by two multi-disciplinary expert teams (the "Markers Panel") to investigate the potential for markers to deter inadvertent human intrusion into the WIPP repository. These studies followed upon earlier studies by the Futures Panel to develop potential scenarios for intrusion, and were conducted to develop design guidelines for markers as well as preliminary forms of messages and formats to be placed on those markers to communicate the location and hazards posed by the wastes in the repository. Both teams agreed with the need to mark the site, and to provide accurate information at several levels of sophistication. Both teams considered the characteristics of a marker system from several points of view, including architectural design, material properties, linguistics and message levels. Both recommended marker systems incorporating elements on a variety of scales ranging from large earthen berms to buried message disks or capsules, and bearing messages at a variety of levels ranging from rudimentary to detailed and technical. Both recommended the use of several languages in messages. Both also recommended the use of durable materials of little intrinsic value. These and other characteristics are addressed in detail in the individual team reports, which are attached as appendices to the report. Areas for further research and investigation were also identified,

including physical properties of marker materials; culture-independent interpretation of graphic or pictorial messages; and culture-independent interpretation of written messages.

- Trautsch Chr. (2011): „Atomsemiotik – semiotische Probleme von Atommüll und Zeichen als Warnungen an die ferne Zukunft". Paper presented at the *Wiener Nuklearsymposium*, 4 October, 2011 and at the round-table *Arbeit an unlösbaren Problemen: Gott und Müll – Ewigkeitsstiftung durch Endlagerungsverpflichtung, Berlin,* 12 April, 2012.
  Slides: http://www.bazonbrock.de/werke/detail/?id=2625
  Abstract: http://www.nuklearsymposium.at/2011/downloads/file/7-atomsemiotik-semiotische-probleme-von-atommuell-und-zeichen-als-warnungen-an-die-ferne-zukunft
  This paper by a former student of R. Posner (see above Posner 1990) discusses potential contributions of semiotics to the issue of communication of warnings to future generations. It analyses the various components necessary to successful "significant communication" and describes three possible communication channels: physical ("traditional" markers with images, icons, etc.), biological (e.g. animals or plants acting as indicators to radiations), and cultural ("atomic priesthood" as described by Sebeok in Posner 1990). The author sees clear advantages in a "Council of the Future" in charge of transmitting complex warnings over generations.

- Und in alle Ewigkeit: Kommunikation über 10 000 Jahre: Wie sagen wir unsern Kindeskindern wo der Atommüll liegt? – *Zeitschrift für Semiotik*, Bd 6, Heft 3, 1984.
  English Abstracts available at:
  http://ling.kgw.tu-berlin.de/semiotik/english/ZFS/Zfs84_3_e.htm
  Special issue of „Zeitschrift für Semiotik", later revised and published as Posner 1990 (see above).

- United Kingdom Nirex Ltd (2005): *Societal stability and implications for radioactive waste management*. UK Nirex Ltd Technical Note no. 483990. Nirex, Harwell (Didcot).
  http://www.nda.gov.uk/documents/upload/Societal-stability-and-implications-for-radioactive-waste-management-A-Technical-Note-2005.pdf
  The purpose of this study was to provide information on the longevity and stability of societies and institutions as a factor in decision making about options for long term management of radioactive wastes, in view of the fact that some proposed options (such as continued long-term storage) depend for their success on continued ongoing management. The method used was to identify and assess a number of historical analogues, including examples of civilisations, organisations and physical artefacts, with a view to identifying factors that may have contributed to their survival. The study found that survival of artefacts is unpredictable; actions or conditions that appeared in some cases to have contributed to preservation were found in other cases to have contributed to loss. It was noted that preservation of a collection of records or items did not necessarily prevent the loss of individual items within the collection. Survival of organisations was generally dependent on the survival of the society in which they exist, and even in cases of survival, organisations often underwent substantial changes with time. Implications of these findings for radioactive waste management were discussed. The report concluded that methods for waste management that rely on continued active management (long-term storage) were unlikely to be successful in meeting safety requirements on the time scales required for management of long-lived radioactive wastes.

- United States Department of Energy / Waste Isolation Pilot Plant (2000): *Permanent Markers Testing Program Plan: Contractor report*. DOE/WIPP 00-3175. Waste Isolation Pilot Plant, Carlsbad (New Mexico).
  http://www.wipp.energy.gov/picsprog/Test1/PM%20Test%20Plan.pdf
  This report outlines a testing program for materials and design features and concepts that are proposed for use in the permanent marker system to be installed at the WIPP site at the time of

repository closure. The proposed marker system includes large surface markers, small subsurface markers, buried storage rooms, an information center, and large-scale earthworks (berms). A program of testing for each of these components, and the materials to be used in them, is outlined. The tests include both initial screening tests and extended tests intended to assess the long-term durability and viability of the marker system components. Program management, quality assurance and requirements applicable to the development and conduct of test and analysis plans are also described. A list of summary descriptions of proposed test methods is included in an appendix.

- United States Department of Energy / Waste Isolation Pilot Plant (1996): *Title 40 CFR Part 191: Compliance Certification Application for the Waste Isolation Pilot Plant: Appendix PIC: Passive Institutional Controls Conceptual Design Report.* Waste Isolation Pilot Plant, Carlsbad (New Mexico). http://www.wipp.energy.gov/picsprog/Test1/CCA_Appendix_PIC.PDF

  This report is part of the Department of Energy's application for certification for WIPP; specifically, it describes the DOE plan for meeting the regulatory requirements related to passive institutional controls. It describes the principles, requirements and criteria established by DOE for the marker system at WIPP. A five-level hierarchy of on-site messages is described, including four levels to be incorporated into the marker system at the site and a fifth level of detailed documentation to be stored at various off-site locations. A proposed conceptual design for monuments and a message storage facility and information centre on the site are presented. A proposed design for surface earthworks (berms) is described, and a testing program for components of the marker system is outlined. Alternative conceptual designs and the reasons for choosing the proposed design over the alternatives are presented. Proposed sites for off-site archival storage for records are listed. Other passive controls such as inclusion of the site on maps and land ownership and land use controls are presented.

- United States Nuclear Waste Technical Review Board (2013): *Review of U.S. Department of Energy Activities to Preserve Records Created by the Yucca Mountain Repository: A Report to Congress and the Secretary of Energy*. U.S. NWRTB, August 2013. http://www.nwtrb.gov/reports/NWTRB%20Legacy%20Mgmt.pdf

  DOE's investigation of the Yucca Mountain site and its development of a license application generated over the 30-year lifetime of the Yucca Mountain project (YMP) massive amounts of technical and scientific information as well as extensive analyses of that information. Following the termination of YMP, responsibility for archiving and preserving Yucca Mountain scientific and engineering information was internally transferred from the unit in charge of the YMP, the Office of Civilian Radioactive Waste Management (OCRWM), to the Office of Legacy Management (LM). The U.S. Nuclear Waste Technical Review Board (NWTRB) was appointed to oversee LM's efforts to archive and preserve YMP documents and materials. Based on the results its review, the NWRTB found that a large part of Yucca Mountain documentation had been preserved and could be accessed and retrieved. Schedules approved by the National Archives and Records Administration (NARA) have been used to identify YMP records that should be preserved either permanently or temporarily (from 10 to 100 years). Some areas of concern have however been identified, including retrieving e-mails, loading and executing analytical software, as well as locating physical objects, such as videotapes, well logs, and maps, for which insufficient search aids exist. Policy-makers should evaluate how much priority should be given to archiving and preserving YMP documents and physical materials, in order to sustain a continuing commitment of resources. Foundational documents developed as part of the YMP should made be easily accessible by the general public on a web platform. Lastly, an external review should determine how materials from geologic investigations and experimental studies – currently not the responsibility of LM – should be managed. [AC, based on original Executive Summary]

- Upshall I., McCarthy G.J. (2007): The development of a contextual information framework model as a potential IAEA strategy to maintain radioactive waste knowledge . – *Proceedings of Waste Management Symposium WM07, February 25 - March 1, 2007*: Global Accomplishments in Environmental and Radioactive Waste Management: Education and opportunity for the next generation of waste management professionals. American Nuclear Society, La Grange Park. http://www.wmsym.org/archives/2007/pdfs/7374.pdf

  Effective inter-generational transfer of information on radioactive waste repositories using 'conventional' techniques will be highly dependent on societal stability – something that cannot be guaranteed over long periods of time. Our understanding of 'inter-generational transfer' should extend beyond the simple physical transfer of records into an archival repository towards the establishment of a working culture that places sufficient contemporary information into a form that ensures it remains accessible, and ultimately enhances, the knowledge of future generations. The IAEA has embraced the contextual information framework as a potentially viable approach to this particular challenge. A contextual framework comprises 'entities' that exhibit one or more definable relationships with a particular 'event'. People, organisations, concepts, ideas, places, natural phenomena, events themselves, cultural artefacts including records, books, works of art can all be conceptualised as entities. The draft IAEA Safety Report entitled 'Preservation and Transfer to Future Generations of Information Important to the Safety of Waste Disposal Facilities' was never published.

- Upshall I.R., Wisbey S.J. (2003): The long-term management of information on records on radioactive waste packages in the United Kingdom. Paper IAEA-CN-90/59. – *International conference on Issues and trends in radioactive waste management*: Vienna, 9-13 December 2002. IAEA, 303-307. Available through INIS: http://inisdb.iaea.org/inis/php/download.php?s=p&rn=34016299

  Careful consideration must be given to the type and form of the information associated with the creation, conditioning and packaging of radioactive waste and the threats to its continued integrity. United Kingdom Nirex Limited (Nirex), in association with experts in records media and management, has undertaken a programme of work to consider the range of media currently available, the threats to media integrity and the implications of a general move towards 'electronic' records. The results of this study are being used to develop an information management system strategy, capable of retaining data for all future phases of radioactive waste management.

- van Wyck Peter C. (2004): *Signs of Danger: Waste, Trauma, and Nuclear Threat*. University of Minnesota Press.
  [not available online, not at Nagra, available for purchase through Amazon]

  History of WIPP to 1999.

- Wagner S., Beauheim R.L., Pfeifle T.W., Bethel B., Sosa-Yates G., Williams C.V., Milligan M., Fox M. (2002): *WIPP case study: Compliance Monitoring, Passive Institutional Controls, and Record Keeping*. SAND 2002-2010. Sandia National Laboratories, Albuquerque, New Mexico. http://www.osti.gov/bridge/servlets/purl/801375-2b1WnW/native/801375.pdf

  This document contains two separate reports: one on the compliance monitoring program at WIPP, and the other on passive institutional controls and record keeping. The compliance monitoring program report describes compliance monitoring parameters selected for both pre-closure and post-closure monitoring, including monitoring of radioactivity, hydrologic and geomechanical parameters, and human activities that could impact the performance of the repository. For pre-closure monitoring parameters, trigger values whose exceedence would result in further investigation have been established. Details of post-closure monitoring will be determined closer to the date of closure. With respect to passive institutional controls, the report describes the guiding principles, marker system design requirements and design criteria for on-site markers and messages, largely consistent with and building on the conclusions of the Markers Panel study

(Trauth et al, 1993). The distribution of records of the knowledge of WIPP to off-site record centers and other regional and national institutions and organizations is also described. The pre-closure record keeping program for WIPP and a proposed records system at the Carlsbad Field Office are described.

- Warner P.J. (1997): United States of America activities relative to the International Atomic Energy Agency (IAEA) Initiatives: Records management for deep geologic repositories. – 1997 Waste Management Conference, March 2-7, 1997. Tucson, Arizona, 1-16.
  http://www.wmsym.org/archives/1997/sess35/35-01.htm
  Presentation of IAEA activities related to the preparation of TECDOC 1097.

- Warner P.J. (1997): *Traceability and retrievability: Documentation, the bridge from science to compliance.* – DOE Records Management Conference: Illuminating our legacy, focusing our future, Las Vegas, 23-26 June 1997. SAND 97-0485. DOE, Washington D.C.
  http://www.osti.gov/bridge/servlets/purl/510334-SkbrUN/webviewable/510334.pdf
  In this day of regulatory compliance, the fact that good science was practiced and documented is, in and of itself, not enough to assure a successful licensing or permitting result. A new level of documentation that clearly walks a non-project reviewer through the traceability of all activities and decisions is required for successful acceptance of scientific results. Compliance reviewers (whether the Nuclear Regulatory Commission (NRC), Environmental Protection Agency (EPA), etc.) expect to verify the results of the scientific and program activities without the physical presence of the person or persons that conducted the activity. Traceability of activities and associated decisions through the retrieval of all associated records is a must. This presentation is based on lessons learned from the various quality assurance (QA) audits and program reviews of Sandia National Laboratories, Nuclear Waste Management Programs Center, scientific and programmatic documentation. The authors build a bridge from science to compliance from lessons learned.

- Warner P.J. (1996): International Atomic Energy Agency (IAEA) Initiatives: Records management for deep and near surface geologic repositories.- *NIRMA Symposium*, August 25-28 1996. SAND 96-2008C.
  http://www.osti.gov/bridge/servlets/purl/366468-5qdZON/webviewable/366468.pdf
  Presentation – aimed in particular at DOE and NARA (National Archives and Records Administration) – of IAEA activities related to the preparation of TECDOC 1097.

- Waste Isolation Pilot Plant WIPP (2007): How will future Generations be warned?
  http://www.wipp.energy.gov/fctshts/PICs.pdf.
  Factsheet describing the various Passive Institutional Controls (PICs) planned at WIPP.

- Weinberg A. (1972): Social institutions and nuclear energy. *Science*, Vol. 177, 7 July 1972.
  [not available online]
  This paper, by one of the key figures in the early development of nuclear energy, reviews what the author considered to be the most troublesome problems in nuclear energy, and then speculates on "some of the new and peculiar demands mankind's commitment to nuclear energy may impose on our human institutions". The author begins with a review of the current (1972) status of nuclear energy development, both once-through and breeder (Pu or Th) fuel cycles. On the topic of environmental effects, he notes that nuclear energy is, or can be made to be, environmentally benign. He discusses the problems posed by the potential for reactor accidents and for accidents during transportation, constituting two of the three most serious problems posed by the technology of nuclear energy. The third problem is that posed by the waste. He notes that the option of permanent storage requires surveillance and active management in perpetuity, and for this reason

opts for sequestration from the biosphere (disposal) in preference. However, he notes that even geological disposal is vulnerable to human intrusion, thus requiring some degree of surveillance to prevent intrusion. In an often-quoted sentence, he states that "We nuclear people have made a Faustian bargain with society", meaning that while nuclear energy offers an almost inexhaustible source of energy, the price demanded is one of "both a vigilance and a longevity of our social institutions that we are quite unaccustomed to". He considers the vigilance aspect, protecting against nuclear and transportation accidents, to be the easier of the two demands to cope with; the requirement for longevity of institutions, in order to prevent human intrusion into and contact with waste, is in his view more problematic. Another often-quoted term used in this paper is that of a nuclear "priesthood"; he notes that permanent storage requires "keeping a priesthood that forever … guards the vaults", and also that we are already reliant on a "military priesthood" to guard against the inadvertent use of nuclear weapons. He expresses the hope that such a "priesthood" will not be necessary to protect wastes in geologic repositories, but does not go so far as to exclude such a need from consideration. This concept of a "nuclear priesthood" was later developed further by Th. Sebeok in the latter's report on Communication measures to bridge ten millennia (1984).
Quoted (excerpts) in Waymire S.D. (2010): Yucca Mountain: The battle for national energy policy, chapter 25
http://www.yuccamountainexpose.com/Y25.htm (whole book available at http://www.yuccamountainexpose.com/home.htm)

- Weinberg A.M. (1999): Scientific Millenarianism. *Proceedings of the American Philosophical Society* 143(4), 531-539.
[not available online]

- Weitzberg A. (1982): *Building on existing institutions to perpetuate knowledge of waste repositories*. BMI/ONWI-379.
[not available online – February 2011]
This report discusses the potential roles of certain existing institutions and practices in preserving and transmitting information to future generations about the existence and location of radioactive waste repositories. The institutions or practices studied include widely distributed maps, focusing in particular on maps produced by the United States Geological Survey; the marker system of the National Geodetic Survey; the retention and archiving of documents in libraries and archives; and the incorporation of waste identification and location into a nationwide "one-call" system for hazardous waste. Each of these approaches is discussed in turn, with a background description, a discussion of methods for applying it to waste repositories, and an assessment of its potential value. The purpose of the study was to supply information to be used in decision making about communication methods to be used for advising future generations about the locations and hazards of waste repositories.

- Wing N.R., Corpus F.M., Peterson K.L., Tallman A.M. (1995): *Physical Stability of Long-Term Surface Barriers - Assessment of Potentially Disruptive Natural Events.* BHI-00145. Bechtel Hanford Inc., Washington.
http://www.wipp.energy.gov/picsprog/Test1/physical%20stability%20longterm%20barriers.pdf
This report assesses the impact of extreme natural events on surface protective barriers designed for near-surface waste disposal sites at the Hanford Site. The events assessed include tornados, high-intensity precipitation, stream flooding, earthquakes, and volcanic ash deposition. A significant part of the report consists of descriptions of site-specific meteorology and climatology, hydrology, geology and seismology, and regional volcanic activity. Appendices document a seismic stability analysis that was performed for a prototype barrier, and laboratory shear tests performed on one of the materials used in the barrier (fluid applied asphalt).

- Wise M., Gray D., Upshall I. (2005): For the record: UKAEA chose to use "permanent paper" to store information on decommissioning wastes from the Windscale Advanced Gas-Cooled Reactor.- *Nuclear Engineering International* 50 / 616, 24-27.
  http://www.neimagazine.com/story.asp?storyCode=2031820
  Radwaste management requires continued access to comprehensive and reliable information over decades and perhaps centuries. The UKAEA has chosen to use 'permanent paper' in preference to electronic systems

- Wray M. (2006): A Blast from the Past: Preserving and Interpreting the Atomic Age. -*American Quarterly* 58(2): 467-483.
  [not available online]

- Yucca Mountain Project (2005): [Fact Sheet:] *The Monumental Task of Warning Future Generations*. Office of Civilian Radioactive Waste Management, Yucca Mountain Project, Las Vegas (Nevada).
  http://www.osti.gov/bridge/servlets/purl/840146-ybac68/webviewable/840146.pdf
  The Nuclear Regulatory Commission (NRC) requires that the monuments or markers accurately identify the location of the repository, be designed to be as permanent as practicable and convey a warning against intrusion into the underground repository. This report discusses the following issues: (1) Post closure issues of underground repositories, e.g., record keeping and markers, public reassurance and prevention of misuse. (2) Optimization of radiation protection by optimizing radioactive waste management, siting analysis, repository design etc. (3) An interface between nuclear safeguards and radioactive waste management by safeguarding conditioning of spent fuel, during operational phase of repository and post-closure phase of the repository.

Various media

- Madsen Michael (2010): *Into Eternity* (documentary film).
  Director Michael Madsen follows the construction of the Onkalo Waste Repository on the island of Olkiluoto, Finland. He questions Onkalo's intended eternal existence, addressing an audience in the remote future. Into Eternity raises the question of the authorities' responsibility of ensuring compliance with relatively new safety criteria legislation and the principles at the core of nuclear waste management. The film explores the question of preparing the site so that it is not disturbed for 100,000 years.
  http://www.intoeternitythemovie.com/

- Desert Space Foundation, Nevada (2003): *Universal Warning Sign: Yucca Mountain* (exhibition).
  The Desert Space Foundation presented an exhibition comprised of winning designs in a variety of media that engage the challenge of creating an effective universal warning sign/permanent marker for the proposed high-level nuclear waste repository at Yucca Mt., Nevada. The purpose of the warning sign is to deter intentional or inadvertent human intrusion or interference at the site and to effectively communicate over the course of the next 10,000 years (the projected duration of the volatility of the waste) that the integrity of the site must not be compromised in any way in order to safeguard humanity from the release of the radiation contained within.
  http://www.desertspace.org/wwwroot/warning_sign/index.html

- Don't dig here, James Crosby
  http://www.youtube.com/watch?v=cg-dEcilplY

- Discussion with illustrations of both the Yucca and WIPP marker concepts on a private (personal) website
  http://www.damninteresting.com/this-place-is-not-a-place-of-honor

- James L. Acord, sculptor, 1943-2011. J.L. Acord included nuclear material in his sculptures.
  http://jameslacord.com/
  See also Acord J.L. (1993): Art in the nuclear age. – *Waste management '93: Working toward a cleaner environment : waste processing, transportation, storage and disposal, technical programs and public education; proceedings of the Symposium on Waste Management at Tuscon, Arizona, February 38-March 4*, 1993, p. 15.
  http://www.wmsym.org/archives/1993/V1/4.pdf

- Cécile Massart, artist
  http://cecile-massart-lisibilite-dechets-radioactifs.com/en/

- Two examples of «nuclear memorials» : Weldon Spring and Fernald

  Weldon Spring Site Interpretive Center
  http://www.lm.doe.gov/Weldon/Interpretive_Center/Interpretive_Center_and_Educational_Opportunities.pdf

  Fernald Preserve Visitors Center
  http://www.lm.doe.gov/Fernald/Sites.aspx

  Fernald Citizen Advisory Board 1993 – 2006 (History of project; see also Krupar 2007)
  http://www.lm.doe.gov/land/sites/oh/FernaldCAB/index.htm

On-going initiatives

Meetings and conferences

Workshop on «Record management and long-term preservation and retrieval of information regarding radioactive waste», held in Rome, January 27-28, 2003.

The proceedings (overheads and papers) were produced as a CD by SKB, Stockholm, 2003 and distributed to the participants.

IAEA Consultants Meetings, Vienna, Austria, March 2002, February 2004, April 2005

IAEA Technical Meeting, Vienna, Austria, June 2004

Club of Agencies Meeting, Paris, 22-23 November 2005 (focus on knowledge management). [overhead presentation available from participants]

IAEA Workshop "Managing nuclear knowledge: Strategies, information management and human resource development", 7-10 September 2004, Saclay.

IAEA Workshop "Managing nuclear knowledge", 22-26 August 2005, Trieste.

IAEA International conference on knowledge management in nuclear facilities, 18-21 June 2007.

NEA Forum on Stakeholder Confidence
The issue of memory and records is often looked at in connection with building a durable relationship to a facility.

Club of Agencies Meeting, Forsmark, 18-19 November 2009 (session on data preservation)

WM2012 Conference, February 26 – March 1, 2012, Phoenix, Arizona, USA: Panel session 34, Geologic Repository Warning Messages to the Future – Ensuring Continuity of Memory and Messages to Future Generations.

Projects

OECD/NEA Project on Long-term preservation of records, knowledge and memory across generations. 2010 – 2013.

- Long-term preservation of information and knowledge: Vision for the RWMC Project on "Preservation of RK&M across generations". NEA/RWM(2011)6/REV2
- 2010 survey on Long-term preservation of information and memory for geological disposal of radioactive waste 18 May 2010. NEA/RWM(2010)7
- [Collective statement]. Status as of 2012.
- Draft glossary of key terms.

Current versions of the documents can be obtained from the RK&M Website. http://www.oecd-nea.org/rwm/rkm/

Waste Isolation Pilot Plant, PICs: http://www.wipp.energy.gov/picsprog/PICs_general.htm

ANDRA, Groupement de laboratoires "Transgenerational transfer and long-time scales", "Knowledge and memory". Contact: Luis Aparicio, ANDRA.

Includes Review of academic literature and benchmarking on very long-term memory associated with RWM, Markku Lehtonen-SPRU, University of Sussex (not publicly available (?))

Relevant treaties, agreements and convention

Council of Europe (2000): European Landscape Convention
http://www.coe.int/t/dg4/cultureheritage/heritage/landscape/default_en.asp

The European Landscape Convention – also known as the Florence Convention, – promotes the protection, management and planning of European landscapes and organises European co-operation on landscape issues. The convention was adopted on 20 October 2000 in Florence (Italy) and came into force on 1 March 2004 (Council of Europe Treaty Series no. 176).

International Atomic Energy Agency (1997): Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management. INFCIRC/546. IAEA, Vienna. http://www.iaea.org/Publications/Documents/Infcircs/1997/infcirc546.pdf

International Atomic Energy Agency (1970): Treaty on the Non-Proliferation of Nuclear Weapons (NPT). INFCIRC/140. IAEA, Vienna.
http://www.iaea.org/Publications/Documents/Infcircs/Others/infcirc140.pdf

United Nations Economic Commission for Europe (1998): Convention on access to information, public participation in decision-making and access to justice in environmental matters: Done at Aarhus, Denmark, 25 June 1998. UN-ECE [Aarhus Convention]. http://www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf

Supplementary list

This heading was created to cater for a series of references to publications and projects that are not directly related to the preservation of RK&M in the context of radioactive waste management, but maybe useful to broaden the discussion. They will eventually be collected into a separate list.

1. Publications

- Damveld H. (2012): Kernafval kwijt. - Technisch Weekblad, 3.12.2012
  http://www.technischweekblad.nl/opinie/commentaar/kernafval-kwijt.293712.lynkx
  Short article on the issue of missing documentation at the Asse mine in Germany.

- Darnay A. (1976): Aspic's Mystery. Initially published in 1976, reproduced in Space Mail Vol. II, ed. I. Asimov, M. H. Greenberg, Ch. G. Waugh, 1982, p. 42-45.
  [Not available online, not at Nagra library]
  According to Sebeok (In Posner 1990), A. Darnay introduced in this short story the concept of a priesthood created to watch the waste.

- Diamond J.M. (2005): Collapse: How Societies Choose to Fail or Succeed (also titled Collapse: How Societies Choose to Fail or Survive). Viking Press.
  [Not available online, not at Nagra, more information at http://en.wikipedia.org/wiki/Collapse:_How_Societies_Choose_to_Fail_or_Succeed]
  Diamond's book deals with "societal collapses involving an environmental component, and in some cases also contributions of climate change, hostile neighbours, and trade partners, plus questions of societal responses". In writing the book Diamond intended that its readers should learn from history *[Wikipedia]*.

- International Journal of Heritage in the Digital Era
  www.multi-science.co.uk/ijhde.htm

- Moxham R. (2001): Great Hedge of India: The Search for the Living Barrier That Divided a People. Carroll & Graf, New York.
  [not available online, not at Nagra. Reference suggested by CP]
  The book describes the author's efforts to discover the remains of a 1500-mile long hedge that the British had grown across nineteenth-century India. Moxham came across the annual reports of the India Inland Customs department, in which the hedge is described. It is likely that the hedge began in the 1840s when thorn bushes, cut and laid along the line as a barrier (known as the "dry hedge"), took root. The principal function of the line was to prevent smuggling, often the only way to procure affordable salt. The hedge was later forgotten and ignored by historians.

- de Vries J.; Schellenberg D.; Abelmann L.; Manz A.; Elwenspoek M. (2013):Towards Gigayear Storage Using a Silicon-Nitride/Tungsten Based Medium. - arXiv:1310.2961
  http://arxiv.org/pdf/1310.2961v1
  Current digital data storage systems are able to store huge amounts of data. Even though the data density of digital information storage has increased tremendously over the last few decades, the data longevity is limited to only a few decades. If we want to preserve anything about the human race which can outlast the human race itself, we require a data storage medium designed to last for 1 million to 1 billion years. In this paper a medium is investigated consisting of tungsten encapsulated by siliconnitride which, according to elevated temperature tests, will last for well over the suggested time. *[Abstract by author]*

- Weisman A. (2007): The World without Us. Thomas Dunne Books, New York.
  More information at http://www.worldwithoutus.com/about_book.html
  [not available online, not at Nagra. Reference suggested by CP]
  Weisman explains how our massive infrastructure would collapse and finally vanish without human presence; what of our everyday objects may become immortalized as fossils; how copper pipes and wiring would be crushed into mere seams of reddish rock; why some of our earliest buildings might be the last architecture left; and how plastic, bronze sculpture, radio waves, and some man-made molecules may be our most lasting gifts to the universe. This book has given rise to a series of TV documentaries on "Life After People". See below and http://en.wikipedia.org/wiki/Life_After_People

- Yates F. A. (1987): L'art de la Mémoire. Nrf Gallimard, Paris.
  [not available online, not at Nagra. Reference suggested by CP]
  This book is about the art of memorizing anything. It utilises as its basis architectural features, so that each part of a building may be associated, say, to a different part of a speech to be given. Can these techniques teach us anything about building monuments that favour memory?

2. Various media

- de Vries David (2008-2010: Life after People (20 episodes documentary film)
  Life After People premiered as a two-hour special on January 21, 2008 on the History Channel. The documentary and subsequent series were both narrated by James Lurie.
  The program does not speculate on how humanity may disappear, stipulating only that it has, and that it has done so suddenly, leaving everything behind including household pets and livestock that have to fend for themselves. The thought experiment is based on documented results of the sudden removal of humans from a geographical area and the results that have occurred when people discontinue the maintenance of buildings and urban infrastructure.
  The series' episodes thematically offer examples of structural and biological decay. The focus is on specific locations like religious icons, bridges and dams, and government buildings, and the fate of certain related objects, such as artefacts, documents and human bodies. The fate of some kinds of flora and fauna are covered as well. Each episode also contains a segment in which experts examine real locations that have been abandoned by people, including ghost towns and other sites of deterioration, where the deterioration has been caused by events similar to those outlined in the episode. Although the fates of landmarks around the world are speculated upon, the main focus is on situations that may occur at locations in the United States.
  The various events that may occur after people disappear suddenly are depicted using CGI dramatizations. Structures covered include the Egyptian pyramids, the Empire State Building, the Willis Tower, the Space Needle, the Eiffel Tower, the Burj Khalifa, the Golden Gate Bridge, the Gateway Arch, Taipei 101, the USS Constitution, the Hoover Dam, the Sydney Harbour Bridge, Grant's Tomb, John Hancock Center and Air Force One. The time line of predicted events begins approximately one day after the disappearance of mankind and extends up to one hundred million years into the future.
  http://en.wikipedia.org/wiki/Life_After_People

- Aftermath: Population Zero (2008). Documentary film
  This is a Canadian series also inspired, like Lifer after People, by the book by Alan Weisman. In addition to Life After People, Aftermath depicts what would happen if various modes of transportation—such as automobiles, planes, and trains—are abandoned in mid-motion when their passengers and operators instantly disappear, not unlike the Rapture in Christian eschatology. Also, Aftermath shows what would happen if a nuclear power plant's spent fuel rods are left without the cooling equipment governing its condition. Life After People suggest that nuclear power plants would safely shut down with no ill effects with no mention of what would happen to spent fuel

rods in storage. However, in an episode of Life After People: The Series, "Toxic Revenge", spent fuel rods are shown 10 days after people heating up and exploding the reactors containing it. Aftermath also shows that the nuclear power plants themselves would shut down without incident, but the spent fuel rod storage in separate buildings would eventually blow up and spread radiation into the air and the surrounding countryside after the backup safety devices fail, due to lack of fuel a few days after the main power plant supplying power shutdown.
http://en.wikipedia.org/wiki/Aftermath:_Population_Zero

3. Technology and Memory / Communication: Projects and organisations

3.1 International projects and events

Communication with extraterrestrial intelligence (CETI)

CETI is a branch of the search for extraterrestrial intelligence (SETI) that focuses on composing and deciphering messages that could theoretically be understood by another technological civilization. The best-known CETI experiment was the 1973 Arecibo message composed by Frank Drake and Carl Sagan. There are multiple independent organizations and individuals engaged in CETI research.
CETI research has focused on four broad areas: mathematical languages, pictorial systems such as the Arecibo message or the Pioneer plaques, algorithmic communication systems (ACETI) and computational approaches to detecting and deciphering "natural" language communication. (Wikipedia).
See in particular NASA conference proceedings: Vakoch D.A. (Ed.) (2011): Communication with extraterrestrial intelligence (CETI). State University of New York Press. (Part III: "Interstellar message construction: Can we make ourselves understood?". See also Part II: "Should we transmit?").

DNA information storage

http://www.ebi.ac.uk/Information/News/press-releases/press-release-01232013-DNA_storage.html
Researchers at the EMBL-European Bioinformatics Institute (EMBL-EBI) have created a way to store data in the form of DNA – a material that lasts for tens of thousands of years. The new method, published in the journal Nature, makes it possible to store at least 100 million hours of high-definition video in about a cup of DNA.
See also Goldmann et al., 2013 and http://www.nature.com/nature/journal/v498/n7453/full/498255a.html
BBC programme at http://www.bbc.co.uk/programmes/b02mqmnh

EUROMED 2014, International Conference on Cultural Heritage, 3-8.11.2014, Lemessos, Cyprus.
http://www.culturalheritage2014.eu/
„Our common goal is to focus on interdisciplinary and multi-disciplinary research on tangible and intangible Cultural Heritage, the use of cutting edge technologies for the protection, preservation, conservation, massive digitalisation and visualization/presentation of the Cultural Heritage content (archeological sites, artifacts, monuments, libraries, archives, museums, etc)." [Conference website]

IAEA: International Nuclear Information System (INIS)

INIS (operated by the IAEA in collaboration with over 150 countries) hosts one of the world's largest collections of published information on the peaceful uses of nuclear science and technology. It offers online access to a unique collection of non-conventional literature.
http://www.iaea.org/inis/

IAEA: Nuclear Archive project (NuArch)

The IAEA maintains Internet Archive of freely available web-based nuclear related information (NuArch). Documents are stored from pre-selected sources in knowledge repository and are available for retrieval. At present, NuArch contains more than 2.2 million documents.

IAEA: Asian Network for Education in Nuclear Technology (ANENT)
http://www.anent-iaea.org/

International Society for Photogrammetry and Remote Sensing (ISPRS / Internationale Gesellschaft für Photogrammetrie und Fernerkundung / Société Internationale de Photogrammétrie et de Télédétection)
http://www.isprs.org/
The International Society for Photogrammetry (ISP) was founded in 2010. Except for interruptions during World Wars I and II, the Society has carried on its activities continuously since its founding.

International Time Capsule Society (ITCS)
http://www.oglethorpe.edu/about_us/crypt_of_civilization/international_time_capsule_society.asp
Organisation established to promote the study of time capsules, based at Oglethorpe University in Atlanta, Georgia. The ITCS is currently setting up a registry of time capsules. The society estimates there are approximately 10,000 capsules worldwide, most of them lost.

Long Now Foundation and 10,000 year clock
http://longnow.org/clock/
For an overview see Alexander Rose: Long Now Salon Talk "Millennial Precedent", San Francisco, April 5th, 2011 (Video)
http://fora.tv/2011/04/05/Alexander_Rose_Millennial_Precedent
This presentation outlines the Long Now initiative and other projects.

Research Center for Semiotics / Arbeitstelle für Semiotik, TU Berlin, Germany
http://www.semiotik.tu-berlin.de/menue/startseite/parameter/en/
See in particular Christian Trautsch, Lecturer, Presentation in the „*Denkerei*“ (dir.: Prof. Bazon Brock) within the framework of the round-table *Arbeit an unlösbaren Problemen: Gott und Müll – Ewigkeitsstiftung durch Endlagerungsverpflichtung*. 12 April, 2012: „Atomsemiotik – semiotische Probleme von Atommüll und Zeichen als Warnungen an die ferne Zukunft”. (http://www.bazonbrock.de/werke/detail/?id=2625)

UNESCO: Memory of the World Programme
http://www.unesco.org/new/en/communication-and-information/flagship-project-activities/memory-of-the-world/homepage/
See in particular the Memory of the World Register: http://www.unesco.org/new/en/communication-and-information/flagship-project-activities/memory-of-the-world/register/

UNESCO Conference: The Memory of the World in the Digital age: Digitization and Preservation, 26-28 September 2012, Vancouver, British Columbia, Canada
http://www.unesco.org/new/en/communication-and-information/events/calendar-of-events/events-websites/the-memory-of-the-world-in-the-digital-age-digitization-and-preservation/

3.2 National Organisations / Discipline History Centres

American Institute of Physics (AIP)
http://www.aip.org/

Arbeitsstelle für Semiotik, TU Berlin as well as Semiotik-Forum
http://www.semiotik-forum.de/

Australian Science and Technology Heritage Centre, University of Melbourne, Australia
http://www.austehc.unimelb.edu.au/
The AUSTEHC is devoted to the preservation, promotion and development of the heritage of Australian science, technology and medicine. Established in 1985.

Archives of the National Research Council Canada
http://www.nrc-cnrc.gc.ca/main_e.html
Canadian Institute for Scientific and Technical Information.

Great Pyramid
http://www.diegrossepyramide.de/
"The Great Pyramid can potentially be any human being's grave or memorial site. As monumental as it is affordable, it serves those of all nationalities and religions. Individuals who are either unwilling or unable to have their ashes buried there can also opt to have a memorial stone placed instead. Stones can be custom designed with any number of colors, images, or relief decorations. The Great Pyramid will continue to grow with every stone placed, eventually forming the largest structure in the history of man.

The Egyptian pyramids were built for eternity but only for one single person. This pyramid is open to every individual. Rather than hastily burying one another or allowing our ashes to be scattered, as a small stone in the pyramid we can remain part of our species' constantly shifting and ever-expanding tableau." An article dated July 2012 suggests that the Great Pyramid has not yet been realised.

Memory of Mankind (MOM) Project
http://www.memory-of-mankind.com/de/home.html
Scientific background: http://www.memory-of-mankind.com/en/facts.html
It is foreseen to store images and texts on stoneware tablets that will be enclosed in Hallstatt's salt mountain (Austria), with a durability expectation of several hundred thousand years. The first tablets have been emplaced on 17 May, 2013.

Swedish Center for History of Science
http://www.cfvh.kva.se/engelska/index.htm

…

4. "Made to last": examples from culture / tradition

At various times, human societies have tried to create structures that would last in perpetuity (though their exact purpose may be lost today):

- Religious buildings and monuments
- Holy books
- Commemorative buildings and monuments, including gravestones, memorials
- Tsunami stones
- …