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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

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Topical Session on Overall Waste Management Approaches

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INTRODUCTION

Area I of a 1999 strategic document of the Radioactive Waste Management Committee[1] (RWMC) deals with "Overall waste management approaches" and identifies the importance of gaining a better understanding of long-term waste management options alternative to relatively prompt disposal. Such understanding is particularly relevant from the point of view of sustainable development and allows to better position waste management within the broader debate on environmental and ethical issues. In particular, it was suggested that one of the points of this reflection is to examine, in parallel to waste disposal in geologic formations, long-term storage and other potential approaches, such as partition and transmutation, in an overall waste management strategy.

The presentations prepared especially for the present topical session are focused mainly on the discussion of management strategies incorporating extended periods of waste storage.

The summaries of the presentations are included in the following section of this document.

The discussions held during the topical session are summarised in the subsequent section.

The full papers or extended abstracts are included in the Appendix.

ACKNOWLEDGEMENTS

The RWMC is grateful to the speakers for their efforts in preparing the topical session and to Mr. Henk Selling for chairing and summarising the session.

1. Strategic Areas in Radioactive Waste Management, NEA 1999.

ABSTRACTS OF PRESENTATIONS

1. Discussions and studies on the “zero” option in Finland

Juhani VIRA, Posiva Oy, Finland

In 1997—1999 Posiva conducted the environmental impact assessment process for the proposed final disposal facility of spent fuel. The assessment was a prerequisite for the application for the Decision-in-Principle on the facility, which was submitted to the Government in May 1999 and finally approved by the Finnish Parliament in May 2001. The assessment of alternatives was an important part of the process. It started from a review of different options for the spent fuel management, but the discussion was finally focused on the comparison between the geologic disposal concept proposed by Posiva and the so-called zero option, which was understood to mean continued interim storage of spent fuel until otherwise decided. The summary of the national discussion and the views the were presented are reviewed.

2. Discussions and studies on the “zero” option in Sweden

Tommy HEDMAN, SKB, Sweden

The zero-option in the Swedish system entails that the present storage of the fuel in the central storage for spent fuel, CLAB, continues indefinitely. CLAB is a “wet storage facility”. In order to shed light on the consequences of the zero-option, the possibilities of prolonged storage of the fuel in CLAB have been investigated. The study included the rock-cavern, building structures, handling equipment and installations in the pools. The result indicates that it is feasible to store the fuel for 100 –200 years if the facility is operated and maintained properly.

3. Technical considerations of long-term waste management

Marcos BUSER, Zürich, Switzerland

The alternatives of long-term storage and geological disposal are reviewed from a social perspective. A distinction is made between guardianship, which requires permanent human control, and a system based on passive safety. Evidence from history demonstrates that social systems are rapidly changing and hardly predictable and consequently not sustainable. This leads to the Swiss model of a long-term monitored underground facility, which is meant to combine the merits of both approaches: human control and passive safety.

4. Long term interim storage: an emerging approach for waste management policy in France

Philippe LECONTE, Direction de l’Énergie Nucléaire, CEA, France

In France, a moratorium is in place on the construction of a geological repository for radioactive waste. This entails the need to explore alternative management alternatives including long-term storage. Extensive experience exists with industrial storage facilities and no major problems are encountered. However, if storage is envisaged for a period of a century or more, more emphasis must be placed on the durability and robustness of dedicated national facilities. No technical limits are foreseen for the feasibility of such a storage facility. It is also recognised that the oversight of such facility will impose a responsibility and a financial burden on future generations. This requires that assurance is achieved regarding the aim of preventing that the storage facility would gradually degrade into a bad repository because of negligence.

SUMMARY OF DISCUSSIONS

Each of the presentations was followed by a brief period of question and answers. At the end of the topical session an opportunity was given for a general discussion on issues of a more generic nature. Highlights of these discussions are given hereafter.

Some questions focused on the appropriateness of imposing burdens on future generations, because this is not considered a responsible action. It was observed that disposal presents a risk, and risk can also be considered as a burden. It was also noted that closing a repository will preclude future generations from taking a decision which they consider more appropriate. In this same context a reference was made to the effect that studies have shown that under certain conditions spent fuel may become a resource. Storage of spent fuel may keep it available for that purpose, should the necessity arise.

The question was raised whether a discussion on long-term storage vs. disposal also takes place in other areas such as management of chemical waste. It was pointed out that at least in some countries, e.g. Germany, the management of chemical waste has come to the fore.

With respect to the French situation in particular, a question was raised on the mechanics of presenting the three available management alternatives (disposal, long-term storage and partitioning and transmutation) to the decision-makers. It was clarified that the three alternatives are linked. If, for example, the partitioning and transmutation techniques had matured to the stage that recycling were an alternative which would reduce the waste amounts substantially, storage would have served a useful purpose by keeping the waste available. In this scenario the amounts of waste requiring eventual disposal would be much smaller.

A question was raised about the implication of the expression “long-term storage”; does it imply that the practice is sustainable for at least 10,000 years, i.e. a time period which is often taken in consideration for demonstrating the safety case of a disposal facility? It became very clear from the responses that long-term storage does not look beyond a few hundreds of years.

From this statement a discussion on terminology ensued. It was remarked that many new terms in connection to disposal have been invented in the last decade, which have not been defined adequately and are being used for different purposes and with different meanings. Although this may reflect the current situation and associated uncertainties in the development of geologic repositories, the public receives a rather clouded picture. As an example, it is may be confusing to distinguish between underground storage, underground disposal, retrievable disposal and monitored disposal.

This again emphasised the need for dissemination of consistent information to the public, because the presentation of different concepts by using terms that are ambiguous even among experts will not contribute much to the establishment of a trust relation with the public. It should also be made clear, however, that irrespective of which alternative will be selected, zero risk does not exist and that people should not expect that.

One of the participants pointed out that the concept of sustainability also includes the continued availability of resources for future generations. This economic aspect was not addressed before in the discussion. Any decision on radioactive waste management alternatives should take proper account of the economic aspect as well.

Much research effort has been place into demonstrating the technical feasibility of deep underground disposal. While this is certainly the most favoured endpoint among experts on radioactive waste, some countries tend to follow – officially and unofficially – a different route or have at least adopted a different speed on the route. Contrary to the point of view by the experts as laid down in numerous international guidance documents, it is not a foregone conclusion that disposal at the earliest feasible time is the only possible endpoint. At least it was apparent from the presentations that alternative strategies are being considered even though these options have only been used for comparison purposes in an EIA. Some countries have clearly stated that a decision in favour of either one of the management options has not been reached by the decision-makers.

APPENDIX I

PAPERS AND EXTENDED SUMMARIES

DISCUSSION OF THE ZERO OPTION IN THE CONTEXT OF POSIVA'S ENVIRONMENTAL IMPACT ASSESSMENT AND APPLICATION FOR THE DECISION-IN-PRINCIPLE

Juhani Vira
Posiva Oy, Finland

SUMMARY

According to the Finnish legislation, the environmental impact assessment (EIA) report is a prerequisite for the Government Decision-in-Principle (DiP), which is needed for any major nuclear facilities in Finland. For the spent fuel disposal facility Posiva carried out the EIA procedure in 1997—1999. The assessment included a review and comparison of various alternatives for geologic disposal, one of which is the so-called “zero” option; i.e., the continuation of the present practice without implementing the proposed disposal concept.

The assessment of alternatives was carried out in several steps, starting from different conceptual solutions for the spent fuel management, continuing to the comparison of different geologic disposal concepts and finally ending at the comparison of the proposed geologic disposal concept, the KBS-3 concept, with the zero option. In the case of Posiva's EIA the zero option was considered to mean continued storage of spent fuel elements in present monitored storage pools. In addition, attention was also given to the so-called zero-plus options, i.e., modifications to present interim storage techniques.

The conclusion from the first step of the assessment was that at present the decision could only be made between the development of the geologic disposal option (either for the spent fuel or the reprocessing wastes) and the zero or zero-plus options. Opting for partitioning and transmutation (P&T) would reduce to the zero option as long as its industrial applicability and the limitations thereof were not known. However, the judgment was made that, according to current scientific assessments, the P&T techniques will never eliminate completely the need for geologic disposal of some radioactive waste.

As alternative geologic disposal concepts a number of proposals from the past ten to twenty years were considered such as the (very) deep hole concept and the WP Cave. Also concepts such as the Medium-Long Holes (MLH) were presented but they were considered to be so close to the proposed KBS-3 concept that they were actually classified as variations of the KBS-3. The conclusion from this step was that the proposed alternatives would not offer significant advantages over the KBS-3 concept but they would certainly require considerable investments in new investigations methodologies without clear promise of success. However, some of the variations to KBS-3, such as the MLH, were considered potentially interesting.

In the final comparison between the proposed KBS-3 concept (or its variation) and the zero alternative it was concluded that both options would offer the potential for safe implementation;

however, the zero option only if continued maintenance of the storage could be assured. In the absence of such assurance the development of the geologic disposal option on the basis of the current KBS-3 concept would offer a better potential for a permanent safe waste solution than the continuation of the zero option. As regards the zero-plus options, it was judged that some of them might offer potential safety advantages over the long-term storage in water-pools, but they would still not make a permanent solution for the spent fuel management. On the other hand, the continued development of the KBS-3 concept would not preclude introduction of improvements or changes to the disposal concept.

In the Parliament discussion of the Decision-in-Principle in 2002 the majority of Parliament members seemed to share the conclusions from Posiva's EIA. Most of the issues raised were related to the question of completeness (whether all alternatives had been considered) and the question of reversibility: whether the DiP could be reversed and whether the Parliament would still have a say in the process. At this stage the majority of the Parliament members took the stance that it would be better to continue with the concept that seems to offer reasonable potential for implementation than just keep waiting for something better to show up.

DISCUSSION AND STUDIES IN SWEDEN ON THE "ZERO-OPTION"

Tommy Hedman
SKB, Sweden

SUMMARY

For the management of spent nuclear fuel in Sweden, the zero-option entails that the present storage of the fuel in the central storage for spent fuel, CLAB, continues indefinitely. Sometimes the zero-option is equated with the alternative of supervised storage. But there is a fundamental difference. Supervised storage is a proposed solution to the waste problem, with several possible technical solutions while the zero-option entails doing nothing compared with today's situation, aside from continued operation and maintenance of CLAB.

CLAB consists of a receiving section at ground level and a storage section located in a rock cavern whose roof is 25–30 metres below the ground surface. All handling and storage of fuel takes place in water pools. The water, which both cools the fuel and shields off the radiation, circulates in a closed system through heat exchangers and cleanup filters. The facility, which was put into service in 1985, was built for about 60 years of operation. To maintain safety, personnel must be present at all times to supervise and maintain the systems. Approximately 100 persons are needed to operate CLAB.

In order to shed light on the consequences of the zero-option, the possibilities of storing the fuel in CLAB for 100–200 years have been investigated. One fundamental premise in the study is that operation and maintenance of the facility is of the same quality as today. Another premise is that the infrastructure around CLAB – i.e. power and water supply, waste disposal etc. – remains intact.

The building structures in the storage section are estimated to have a lifetime of about 200 years. A follow-up programme indicating the need for repair and renovation of certain parts would be required, however. Rock reinforcements cannot be projected to last 200 years based on present-day knowledge. Here a follow-up programme and replacement of certain parts will be necessary. Installations and handling equipment generally have a limited service life, but can be replaced and modernised. The same applies to electrical and control-equipment. Modernisation and replacement of components is performed continuously in CLAB even today.

Provided that the quality of the water meets relevant specifications, it is judged that the fuel can be stored in water for a long time without suffering damage. However, experience and research are lacking to assess the consequences of storage beyond 100–200 years.

The study also contains an analysis of possible accidents during prolonged storage at CLAB. The analysis shows that the consequences for the surrounding environment of accidents during prolonged storage decreases with time. At the same time, the time margins for rectifying operational disturbance increases, since the activity of the fuel, and thereby its heat output, declines with time. As

a result, even severe accidents, which could result from ageing, will have limited consequences for the surrounding environment.

All factors considered it can be assumed, that CLAB – with certain renovation and modernisation measures, and as long as our present-day society lasts – can be operated safely for 100 years or more.

What happens if the facility has to be abandoned due to e.g. war or environmental disasters? Even if, for example, important pumps should stop, it will take around a month before the water in the pools has evaporated to the point where the fuel is exposed. But if more water has not been added by then, the temperature can become so high that the fuel is damaged. In the worst cases, the radiation doses may then be relatively high (on the order of 10–100 mSv/y /4-28/).

The fuel in CLAB can only be exposed if more water evaporates due to heating by the fuel than flows into the facility from the surrounding rock. After storage for approximately 250 years, the decay heat in the fuel will have decreased so much that the water does not evaporate any more. The point in time when CLAB is abandoned is thus crucial for the consequences. Another factor of importance is whether the facility has to be abandoned immediately, or whether some advance warning is obtained so that measures can be taken to mitigate the consequences for the surrounding environment.

One serious consequence of abandonment of CLAB is if the facility were to be contaminated to such an extent that resumption of control and management of the fuel at a later date would be difficult. Retrieving the fuel from an abandoned CLAB would, in other words, be a difficult and risky venture.

In the short term, the zero-option entails continuing to operate CLAB in the same way as today while replacing ageing parts of the facility as needed. Environmental, safety and radiation protection requirements will be complied with as long as supervision and control are maintained. However, we can neither expect nor ask that future generations should set aside resources for supervision and maintenance far into the future. If supervision and control should for some reason cease, the consequences could be serious.

One risk if interim storage in CLAB is prolonged and no additional measures are taken to manage the spent fuel is that we will lose the competence that has been built up to manage and dispose of spent nuclear fuel in a safe manner. This includes the technical- and scientific-expertise possessed by regulatory authorities and SKB as well as general knowledge possessed by national and local politicians and the general public.

TECHNICAL AND NON-TECHNICAL CONSIDERATIONS ON LONG-TERM WASTE MANAGEMENT

Marcos Buser
Zürich, Switzerland

SOME THOUGHTS ON THE RELATIVITY OF KNOWLEDGE

Saint Augustine, one of the most eminent Christian bishops and philosophers of late Antiquity, had a broad impact on thinking throughout the whole Middle Ages. His contribution to the philosophical debate on knowledge was founded on a closed and irrevocable system conceived from the Holy Scriptures. Some 1100 years before Descartes, Augustine raised the question of the status of human knowledge in an only partially understandable, rational world. In contrast to Descartes, who shaped the modern rational and cognitive approach to science through his famous "cogito ergo sum", Augustine believed that absolute and definitive truth was only possible through a spiritualized relation to the Lord. The materialistic, exterior world, he claimed, is a world of illusion, doubt and error. "Si enim fallor, sum" – "If I am wrong, I am", is the shortened form of this insight. [2]

With this conception of the world, Augustine had taken up the world view of Antiquity, as manifested by sophist and skeptical thinkers[3]. However, Augustine reinterpreted these findings in a metaphysical way. Doubts and errors were confined to this earthly world and was the proof that real knowledge needed faith: "Believe to see (know), see (know) to believe".[4]

Even though these reflections were developed from different perspectives, Augustine's approach to the status of reality or knowledge is quite modern. The debate on scientific progress and epistemology, started many decades ago, revolves around questions such as the objectivity of perception, and the influence of "faith" on "truth". Particularly in social sciences, doubts arose as to the objectivity of perception and led to a reconsideration of the scientific methodology behind "truth"-finding. Even in the fields of natural sciences and the history of science, the positivistic scientific approach[5] became questioned. The doubts even went so far as to dismiss the existence of ultimate scientific "truth". However, what revealed itself more and more visibly was that the terminology of science was not adequate as a sole guarantee of objectivity. Thomas Kuhn, for example, showed, in his study on "The Structure of Scientific Revolutions", that the changing process of theories and systems of theories ("paradigms") is characterised by a continuous shifting of the terminology and relies

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2 Augustinus Aurelius (1991): Vom Gottestaat (De civitate dei), dtv klassik, Book 11, Chapter 26, Vol. 2, p. 43.

3 See e.g. the theorems of Protagoras, Gorgias, Pyrrhon of Elis, Sextus Empiricus, cf. Helferich Christoph (1992): Geschichte der Philosophie, Verlag J.B. Metzler. The specific „rationalism" of Greek philosophers is well described by Dodds Eric Robertson (1991): Die Griechen und das Irrationale, Wissenschaftliche Buchgesellschaft Darmstadt, p. 96-97.

4 dtv-Atlas zur Philosophie (1991): Deutscher Taschenbuch-Verlag, S. 69.

5 Cohen Bernhard I. (1994): Revolutionen in der Naturwissenschaft, Suhrkamp, p. 450.ff.

therefore on different and changing perceptions [6]. Karl Popper argues in a similar way: knowledge is not a result of a systematic process of perception which comes from separate observations, leading to the development of more and more general and universally valid natural laws. Knowledge, as established in laws and theories, remains, in fact, incomplete and uses or processes only a (very) limited part of the available information, which can furthermore be interpreted in different ways [7]. Therefore, knowledge simply reflects the knowledge of a period (and culture). However, these scientific approaches do not question the reality-concept of the world[8].

In contrast to this conception of rational science, doubts have been formulated about the basic methodology used in the process of accumulating scientific knowledge. Feyerabend, for example, stated that knowledge was not a succession of theories free of contradictions, which converge towards an ideal theory, nor is it a gradual convergence towards "truth". It is merely a growing "sea" of incompatible and even incommensurable alternative theories[9]. Modern constructivism is even more radical. The basic tenet of the different constructivist currents is that knowledge is just a construction or creation of the observer and reflects, therefore, the observer's subjective perception of the world[10]. Radical constructivists even go so far as to question the term and concept of reality, replacing it with an image of absolute relativity of perception (through the term of autopoiesis), and therefore of knowledge.[11]

METHODOLOGICAL APPROACH IN THE FIELD OF NUCLEAR WASTE MANAGEMENT

It is not the aim of the present exposition to start an epistemological discussion on the extent to which the positivist approach to the process of accumulating scientific knowledge can be brought into accordance with the constructivist image of created and subjective universes. In the context of nuclear waste management, however, questions arise as to which scientific methods should and could be used in order to promote progress of knowledge, and to what extent methods of scientific prediction based upon this traditional knowledge-process can effectively be developed and applied. The use of these methods is of great concern, because scientific and political decisions of great impact depend on them.

What should rather be focused on, in the context of nuclear waste management, is the search for and increase of adequate knowledge by the elimination of inconsistent methodologies, theories

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6 Kuhn Thomas S. (1997): Die Struktur wissenschaftlicher Revolutionen, suhrkamp taschenbuch wissenschaft.

7 Popper Karl (1934): Logik der Forschung, in Helferich Christoph (1992): Geschichte der Philosophie, Verlag J.B. Metzler, p. 386.ff.

8 Hull, David L. (1988): Science as progress. An evolutionary account of the social and conceptual development of science. The University of Chicago Press, Chicago, London, p. 111.ff.. Hull comments the wide perceptions and reactions of Kuhn's book

9 Feyerabend Paul (1993): Wider den Methodenzwang, suhrkamp taschenbuch wissenschaft, p. 34ff.

10 Maturana Humberto, Varela Francisco (1987): Der Baum der Erkenntnis, die biologischen Wurzeln des menschlichen Erkennens, Goldmann, p. 258-259; Collins Harry, Pinch Trevor (1999): Der Golem der Forschung, Wie unsere Wissenschaft die Natur erfindet, Berlin Verlag, p. 216-217;

11 Watzlawick Paul, editor (1985): Die erfundene Wirklichkeit; Piper; Watzlawick P. / Kreuzer F. (1988): Die Unsicherheit unserer Wirklichkeit, ein Gespräch über den Konstruktivismus, Piper, p.46: "May be that biologists and science theorists will criticize me, but in my opinion the radical constructivism is right when he states: What research is telling us, is what reality isn't" (Möglicherweise werden mich die Biologen und Wissenschaftstheoretiker kritisieren, aber ich bin der Meinung, dass der radikale Konstruktivismus recht hat, wenn er sagt: Was uns die Forschungen erklären, ist, was Wirklichkeit nicht ist"

and/or strategies. In this sense, Popper's approach on falsifiability is very useful. This approach rejects the way of "truth"-finding by a process of increasing generalization of individual cases or empirical findings (induction), replacing it by a process of refutation or disproving of the acquired knowledge (falsifiability), leading in this way to a gradually more precise description of "truth". Lakato's proposition for the evaluation of scientific research programs, including a characterization of their progression, stagnation or degeneration, aims in a similar direction[12]. This approach is particularly interesting in our context because he includes „disputes between advocates of different research programs" (see Hull, p. 300), which also means of different ideological currents.

A final methodological element often employed by constructivism may complete our methodological tools. As a key fits, or does not fit, the lock, so the process of fitting perception, knowledge or data to theoretical findings ensures a critical approach, by reviewing the results of confrontation of different scientific (or non-scientific) conceptions.

WASTE MANAGEMENT STRATEGIES

An analysis of the very extensive literature on nuclear waste management strategies since the end of the 1940s shows a strange convergence of concepts for the ultimate disposal of radioactive wastes (see Table 1). Numerous strategies were suggested and applied at the beginning, such as sea-dumping, dilution of radioactive sludges in sea, seepage of liquid wastes in ponds and pits (e.g. ORNL, Hanford), or injection into decommissioned oil wells. The possibilities of controlled long-term storage for indefinite periods of time (e.g. mausoleums, surface disposal in prohibited arid areas) were also explored but were later mainly dismissed by the nuclear scientific community[13]. Options such as transmutation and space disposal appeared after reprocessing became available and the Soviet Sputnik circled around the world. However, the evaluated strategies soon converged towards ultimate geological disposal in continental formations or under the sea-bed[14]. All rock formations proposed for this purpose in the early stages of research (clays, evaporites, crystalline rocks, tuffs) are still undergoing detailed study. However, the sub-seabed option has been abandoned due to problems related to international law, long-term protection of the oceans and public acceptance.

Despite the considerable progress made in the last two decades in the study and realization of deep underground repositories, long-term storage strategies, involving monitoring over thousands of years, recently re-emerged, at the end of the 1980s. Initially, the rebirth of this controlled storage strategy was promoted by various schools of thought which can be brought together under the heading of "nuclear guardianship". Originally supported mainly by "green" movements with strong mystical and romantic roots, the idea of guardianship quickly gained popularity, and was later - and for other reasons - taken over by strong political movements, such as Greenpeace[15].

Parallel with these movements, similar strategies were reintegrated in the evaluation of major nuclear waste management programs (USA, Canada, France). The French program, established by a law adopted in 1991 (loi Bataille), is based on three strategies, which will be followed officially until

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12 Hull David . (1988): Science as a progress, an evolutionary account of the social and conceptual development of science, The University of Chicago Press, Chicago, London, p. 299-300.

13 Some later publications were exceptions (cf. Hammond Philipp R. [1979]: Nuclear waste and public acceptance, American Scientist, Vol 67).

14 An option raised in early 1950s by Woodshole Oceanographic Institute, USA, and later picked up by the sub-seabed disposal programme under leadership of Sandia Laboratories, Albuquerque USA.

15 See, for instance, Greenpeace (ohne Jahrgang): Trittst im Morgenrock daher, seh' ich dich im Strahlenmeer, Greenpeace Schweiz

2006: (1) underground disposal, relying on passive safety systems, (2) long-term storage, relying on active participation of society, and (3) transmutation[16]. Similar programs are running in the USA and Canada. This evolution is a result of growing public concern about the previous policies of nuclear waste management by the implementing organizations, which are increasingly experienced as too narrow. However, it is questionable whether the broader, redefined programs will really be able to achieve more acceptance than those based solely on ultimate disposal. Acceptance not only depends on quality of scientific programs but is also strongly influenced by a different risk perception in industrial societies, as well as by contradictory technological and political outlooks[17].

CONSIDERATIONS ON ETHICS AND IDEOLOGY

It is precisely a several decade-old conflict related to the peaceful use of nuclear energy that weighs heavily on the programs for waste disposal. Effectively, debates on nuclear waste management have replaced the older conflicts centred on nuclear energy production, since power plant construction has practically ceased. For more than a decade, the struggle between supporters and opponents of nuclear energy has turned around the future of nuclear technology. The whole nuclear fuel cycle, in general, and radioactive waste management, in particular, are used as a pledge by opponents in order to scotch as quickly as possible the nuclear “adventure”. The key argument is that the problem of nuclear waste disposal is not solved, never will be solved and, indeed, cannot be solved. Green movements conjure up in dark colours the risks of underground disposal, the lack of knowledge in geology and hydrogeology, the weakness and even impossibility of modelling and predicting the future, and, therefore, the irresponsibility of all nuclear power programs. Many lament the fate of humanity, conjuring up the enormous burden that our generation will transmit to our descendants for thousands of years[18]. The absoluteness of these public declarations recalls older statements from the promoter side in the 1970s and early 1980s, when nuclear waste disposal was declared categorically as having been solved[19].

Often, the different involved stakeholders look upon such statements as representing ethical viewpoints on how to manage the problem. However, modern ethics does not include moral attitudes as to what is “good” or “bad”, but aims at defining what is more or less “just” within a broader and more complex social system, including present as well as future generations (IAEA). In this context, questions must be addressed about the ethical content, both of the current waste management strategies, and of the long-term surface storage of radioactive wastes supported by the opponents of current practices. Is it an acceptable ethical basis to burden future generations with a problem considered to be scientifically insolvable by promoting a socially controlled risk system? Are social structures really prepared to take over responsibility in order to ensure the required radiological protection over the involved time-spans? What conclusions can be deduced from historical knowledge and analyses about the possibilities of safe storage over hundreds and thousands of years and as a

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16 Dautray L. (2001): L’énergie nucléaire civile dans le temporel des changements climatiques, rapport à l’Académie des sciences, Paris, Editions TEC&DOC, 11 rue Lavoisier, 75 008 Paris, Londres – Paris – New- York;

17 MCombie Charles (1997): In the eye of the beholder: different perceptions of the problems of waste disposal, Nagra-Bulletin, Nr. 30, p. 18-19

18 Buser Marcos (1998): „Hüte“-Konzept versus Endlagerung radioaktiver Abfälle: Argumente, Diskurse und Ausblick, Expertise ordered by the Swiss Federal Nuclear Safety Inspectorate, CH-5232 Villingen, p. 22-24

19 Buser Marcos (1988): Mythos „Gewähr“ – Geschichte der Endlagerung radioaktiver Abfälle in der Schweiz, Schweizerische Energie-Stiftung

long-term source of risk to society? And what are the technical requirements and economic impacts of the considered strategies of long-term storage?

As indicated above, no scientific method exists for reaching “truth”, and the search for knowledge is to be considered as a step-by-step process leading gradually to a better understanding of “reality”. In this process, inconsistent knowledge should, as far as possible, be eliminated. Comparative analyses of contradictory theories, facts or plans can help to identify and select less diverse or problematic conclusions or no-go issues. Within this context, we should consider some crucial points, in order to evaluate the feasibility of the debated strategies for nuclear waste management. Our attention will be focused particularly on four points:

- On the methods and problems of prognostics in relation to complex systems.
- On problems related to the ideological status of radioactive waste.
- On the way in which societies have dealt with ideological items historically.
- On questions related to technical robustness and technical development.

PROGNOSTICS IN RELATION TO COMPLEX ENVIRONMENTAL AND SOCIAL SYSTEMS

As already mentioned, the strategy of long-term surface storage is based on the assumption that developing a geological system which is sufficiently safe is inherently impossible because of the unreliable nature of scientific prediction. Following this thread of argument, the question must be raised whether the evolution of social systems can predicted more reliably in order to ensure safe long-term storage over the involved time-spans. Simple considerations about system dynamics and the scales of movements in different media show that movements in the lithosphere are generally many orders of magnitude smaller than those in atmosphere, hydrosphere or biosphere (Table 2). If the rates at which processes occur are linked to the reliability of predictions, it soon becomes clear that social developments can, at best, be predicted over periods of the order of a few decades (Table 3). Looking back over the last decade, some major, unforeseen social and economic events or changes become evident, such as the fall of Soviet empire, the spread of Islamic fundamentalism and terrorist attacks, or the crash of the “New Economy” in the past year - all events which were not predicted by the involved systems. Contrary to the tenets of dialectical materialism, the future of society is neither controllable nor predictable on the long-term and it is clear that social evolution is considerably more uncertain than geological change occurring - at the quickest - on scales less than a few centimetres a year. These simple reflections should be sufficient to eliminate definitely the strategy of long-term surface storage of radioactive waste, controlled by society. In addition, as we shall see in the following discussion, surface storage increases the attractiveness of waste and therefore the risk of mismanagement.

PROBLEMS RELATED TO THE IDEOLOGICAL STATUS OF RADIOACTIVE WASTE

Three major sources of interest - and therefore of potential misuse – exist in relation to radioactive waste. The first is related to the high risk of the waste itself. In fact, there is a pronounced ambivalence in modern societies between the perception of danger and risks and the way the problems of risk management are tackled politically. Influential movements in western industrial societies are opposed to the proposed solutions of underground disposal and create a climate of distrust in which waste management is stylized to an insolvable problem. Through this policy, defence positions of local opposition movements (“NIMBY”-attitudes) are not only reinforced, but a general attitude towards risk perception is also generated in order to be used as a political instrument and as a pledge against nuclear power generation. These linkages completely mask the real nature of the scientific problem and support an ideological and sometimes even mystical[20] approach to dealing with waste management options. As we will see further, this ideological component is a major source of concern when socially controlled strategies of waste management are considered. It can be foreseen that waste storage and even disposal projects will be subject to extremely close vigilance by some interest groups and that Argus eyes will be kept on them, even after repository closure. Public unrest will probably remain at a high level as long as fear and inquietude exist, and as long as major interest in reusing the wastes is still alive.

Precisely this latter point is a second and third reason for concern, the potential for use and misuse. The potential reusability of spent nuclear fuel may keep awake the interest of technically highly-developed societies in radioactive waste in future – not only as a valuable resource (future use), but also for military reuse or terrorist aims (future misuse). From the point of view of long-term safety, it is evident that closed deep underground repositories are much better shielded against misuse than long-term surface storage facilities. As history tells us, high risks of misuse will remain, as long as economically or strategically valuable resources are under direct social control. Even for the deep underground facilities, these dangers must be kept in mind. It would be recommendable to reanalyze – as proposed by Dautray - the options of reuse of fuel[21] prior to waste disposal and to reinforce the reflections made by NEA on this topic[22]. As long as some use is still available for the waste, waste facilities will be a focus of interest in the concerned societies.

However, of the three potential sources of misuse the first is probably the one which is the more difficult to deal with. Fundamentalistic world conceptions are particularly susceptible to undifferentiated violent eruptions and may cause major harm when considered with dangerous technologies.

HOW SOCIETIES HAVE DEALT WITH IDEOLOGICAL ITEMS IN HISTORY

The destruction of the 2000 year old Bamian Buddhas in Central Afghanistan and, in general, the older cultural heritage, by the Taliban government in 2001 shocked enlightened opinion in Western industrialized countries. However, voluntary devastation of this type has been a feature of fundamentalistic ideological movements throughout history and in many parts of the world. The basic aim of such movements is to blur methodically the cultural and religious identity of dissident world conceptions. In this sense, the Nazi Holocaust is – until now – the best organised attempt to destroy cultural heritage and the identity of several nations. The Nazi example also shows that such developments are still possible in the so-called civilized world, if economic or political conditions lead to major social crises[23].

Looking back in history, similar attitudes of fundamentalistic or autocratic governments, movements and groups become evident in their attempt to impose the „good way“ in this very bad

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[20] See Buser M. (1998): „Hüte“-Konzept versus Endlagerung radioaktiver Abfälle: Argumente, Diskurse und Ausblick, Swiss Federal Nuclear Inspeactorate, CH-5232 Villigen

[21] Dautray Robert (2001): L’énergie nucléaire civile dans le cadre temporel des changements climatiques, rapport à l’Académie des Sciences, Editions Tec et Toc, 11 rue Lavoisier, 75 008 Paris

[22] NEA/AEN (2001): Reversibility and Retrievability in Geologic Disposal of Radioactive Waste, NEA/OECD

[23] The newly emerging historical discussion on externsive surface destruction of civil targets in Germany by allied forces at the end of World War 2 is evidence that even civilized nations may fall into barbaric practices

world[24]. Historical analyses support the conclusion that conflicts with high ideological and unilinear content lead, very often and in a very specific way, to the destruction of the ideological and cultural background of the defeated parties. Some examples can serve to illustrate these conclusions. The cultural and religious identity of Antiquity was voluntarily destroyed by upcoming Christianity towards the end of the fourth and the beginning of the fifth centuries. With some exceptions, most of the temples and the religious and cultural identities of the Roman Empire were razed to the ground in a time-span of only a few decades. Similar devastation can be observed during the advance of Islam in the 7th century, in the southern and eastern parts of the Mediterranean basin, and later – in the opposite direction – after the Reconquista of southern Spain and Portugal by the autochthonous Christian kingdoms. The same methods were applied in the conflicts between Protestants and Catholics – as we can see in the England of the17th century.

In contrast to this destruction, we can observe more or less stable ideological conditions during the Middle Ages in the major European continental areas. Roman and Gothic buildings have mostly been preserved, which means that the threshold of ideological clash was not reached during this epoch. However, even such long periods of ideological "continuity" should not lead us construct stable worlds and "ends of history". History remains unpredictable – contrary to the tenets of Hegelian or dialectic materialistic conceptions.

TECHNICAL ROBUSTNESS AND TECHNICAL DEVELOPMENT

The long-term societal impact of radioactive waste management has been recognised and discussed for many decades[25]. That was precisely the reason why attention was focused on deep underground disposal, and why surface storage options and strategies were quickly dropped. The need to keep communication structures active over time-spans of hundreds, thousands, even tens of thousands of years, and the unusual technical and economic challenges and burdens of such plans, make it illusory to guarantee the required levels of societal, technical and financial continuity needed for these purposes. Robustness of a long-term effective management system for radioactive waste implies that simple and stable conditions be established and maintained - which cannot be attained in a dynamic societal process. Once more, history gives us striking arguments to refute safety systems based on long-term active measures and plans. No or little experience exists for the management of reparation and long-term monitoring funds. No prognostics are available for long-term technical expenditures and the associated long-term costs. Even the remaining buildings or infrastructures of Antiquity, constructed with durable materials and still in operation today – such as Porta Nigra in Trier, the Pantheon in Rome, or Segovia's aqueduct – have had to be maintained and repaired continuously.

Rough calculations made for this purpose in connection with some Swiss municipal waste landfill projects showed that considerable financial reserves must be built up in order to fulfil the legal requirements of safety[26] - and this only for some decades. Other calculations have been done for the technical maintenance and the replacement of defect installations (drainage systems, leachate control,

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24 See the large classical literature in this context, e.g. Cioran Emile (1960): Histoire et utopie, folio essays; Cohn Norman (1970): Das neue irdische Paradies, revolutionärer Millenarismus und mystischer Anarchismus im mittelalterlichen Europa, Rowohlts Enzyklopädie

25 See Proceedings of The Fourth International Conference on the Peaceful Uses of Atomic Energy, Geneva 6-16 september, IAEA, Vienna 1972, Vol. 11, p. 465-471

26 Of the order of millions to dozens of millions of Euro for 50 years (Canton of Zürich) and up to 25% of the investment-costs for a time span of 100 years.

reparation of cover, etc.), as well as the costs due to these operations.[27] The results have been disappointing, with the expected life span of these elements varying from several decades to several hundreds of years at best, and with long-term costs exploding (see Table 4). Additionally, the acceptance of such long-term financing systems would first have to be demonstrated.

Technical progress must clearly be included in this type of consideration, although there is a major difficulty in predicting the direction and speed of technical and technological developments, even over small time-spans (see Table 4).[28] Furthermore there are no indications that revolutionary new technologies for radioactive waste treatment or encapsulation are underway, which could change the scope of waste management strategies. On the contrary: since the beginning of radioactive waste management, there has been a step by step optimization of procedures and technologies to ensure the required radioprotection standards in waste disposal programs. From whichever point of view one looks at long-term storage, the required robustness of a durable technical, environmental, economic and political handling is, at the moment, neither proven nor expectable[29]. Hence, there is no technical, economic or political reason to re-question the general policy aim that radioactive garbage should not be bequeathed to future generations, as Alvin Weinberg pointed out already 30 years ago[30].

OUTLOOK

The still on-going discussion on underground disposal versus long-term storage in controlled facilities reflects the old debate about the significance of passive versus active measures for repository safety. As shown in Table 1, major emphasis was laid in the past on passive safety systems and final underground disposal. However, the final uncertainty of prognostics in geological systems leads some authors to raise questions about the sense and necessity of additional measures. In the course of the years, different concepts have been proposed, including the additional need for long-term monitoring and retrievability of wastes (see LBL, Hammond, Buser+Wildi, Roseboom, Flueler)[31]. Today, it is commonly accepted that these items must be concretely treated in future waste disposal programs.

In Switzerland, the discussion on nuclear waste management was extended in the 1990s and led to an extended debate, the so-called "Energy Dialogue", in which operators, authorities and environmental organizations were represented. The final report of this dialogue commission, compiled in 1998, recommended a bridge-building strategy between the positions of geological disposal promoted by the operators and the guardianship concept defended by the nuclear opponents. Therefore, Federal Councillor Moritz Leuenberger set up an Expert Group on Disposal Concepts for Radioactive Waste (EKRA) in June 1999, and asked for a critical review of all concepts and strategies

27 Calculations done for the Oberholz landfill project, Suhr, Aargau.

28 Kowalski Emil (2002): Technology Assessment, Suche nach Handlungsoptionen in der technischen Zivilisation, vdf, Hochschulverlag an der ETH Zürich

29 See also Flüeler Th. (2001): Options in radioactive waste management revisited: a proposed framework for robust decision making, Risk analysis, Vol. 21, N0.4

30 Proceedings of The Fourth International Conference on the Peaceful Uses of Atomic Energy, Geneva 6-16 september, IAEA, Vienna 1972, Vol. 11, p. 467

31 LBL (1978): Geotechnical assessment and instrumentation needs for nuclear waste isolation in crystalline and argillaceous rocks, Symposium Proceedings, July 16-20, 1978, LBL-7096; Hammond R. P. (1979)Nuclear wastes and public acceptance, American Scientist, Vol. 67; Buser M., Wildi W. (1979): Wege aus der Entsorgungsfalle, Schweizerische Energie-Stiftung, Zürich; Roseboom E. H. (1994): The case for retrievable high-level waste disposal, Proceedings of the International Conference on High-level Radioactive Waste Management, Las Vegas; Flüeler Th. (2002): Radioaktive Abfälle in der Schweiz, Muster in der Entscheidungsfindung in komplexen soziotechnischen Systemen, Verlag im Internet

discussed in the context of radioactive waste management. EKRA experts focused their attention on retrievability and monitoring, and presented the concept of “monitored long-term geological disposal” in their report of January 2000[32].

The basic idea was to divide the underground repository into three different facilities. Although this idea was not new[33], EKRA adapted it to the requirements of a step-by-step procedure in which repository safety based on active measures was progressively replaced by passive safety systems. Key issues, such as monitoring and retrievability of wastes, were handled in such a way that surveillance and intervention options were kept open over longer time-spans. However, the system could be safely closed at any time, if social decisions or constraints made it necessary.

Three facilities were considered (see Figure 1). The test facility was conceived as a conventional rock laboratory, where the adequacy of the site and the general feasibility of the disposal concept should be demonstrated. Only after this demonstration, should the main facility and the pilot facility be realized. The main facility, where the bulk of the radioactive waste (up to 99% or more) would be emplaced, would be operated and backfilled immediately after emplacement of the waste canisters. It is not intended to keep this facility open longer than necessary. The small remainder of the waste (<1%) would be placed in a pilot or validation facility which would then be monitored over longer time-spans. Access shafts would also be kept open and possibly other special monitoring tunnels in the far field of the repository. The pilot or validation facility serves as a long-term testing and demonstration facility, where predictive models can be verified and monitoring assured. All tunnels which would be held open during longer time-spans (decades and more) would be equipped with self-closure mechanisms, in order to ensure definitive isolation of the repository in case of failure of the social systems. The details of this "monitored, long-term geological disposal" concept are being worked out at the present time.

CONCLUSIONS

Comparing waste disposal and long-term storage strategies from the ethical, technical, social and economic points of view results today in four major conclusions:

1. Risks resulting from nuclear waste should be eliminated as far as possible without delay, with competent methods and adequate knowledge and staff. There is no reason for opening the doors for a strategy of long-term storage of nuclear waste.
2. Social systems are not predictable – not even over time-spans as short as a few decades. In contrast to the conceptions of dialectical materialism, which are based on scientific predictability of history, the „end of history“ is open, as is the scope and direction of technical progress.
3. Hence, socially based nuclear waste programs are not sustainable. The principle of intra-generational equity is violated by placing the burden of further waste management decisions on future generations. This does not mean that future generations are not free to implement new technical progress in the waste management systems conceived today. However, the duty of our generation is to conceive and realize a waste management system capable of ensuring long-term safety without further participation of society. At

32 EKRA (2000): Disposal Concepts for Radioactive Waste, Final Report. Swiss Federal Department for the Environment, Transport, Energy and Communication, 31st January 2000. Available from: Federal Office of Energy, CH-3003 Bern

33 See, for example, the old conceptions of LBL (1978), op.cit.

the present time, only deep underground repositories fulfil this condition.

4. Periodic re-evaluation of waste management strategies, including social criteria and historical knowledge, is needed. A risk assessment of socially based radioactive waste management must include historical evidence, especially concerning major social crises and over longer historical time-spans. We should also analyze problems from the point of view of the needs of countries outside the rich Western industrial world. There may be some evidence there on what might be done and what should not be done when considering socially controlled nuclear waste management.

It is evident that the implementation of such programs needs active and engaged support from politics, and especially from governments. Dialogues between the different stakeholders are certainly necessary in order to establish full transparency and obtain support from the principal societal actors. But implementation is only possible if there is a representative and independent body which is willing to stand deputy for society with regard to a politically unpleasant, and even embarrassing, but urgent problem. Only governments can play this role.

Coming back to the basic methodological questions, we must admit that objective scientific methods for prediction of future developments in social sciences and history are not available, and that "truth", as conceived by metaphysical thinking or even positivism, cannot be obtained in this way. What is however possible is to better understand past developments through a broad historical approach and to include some general reflections and findings on the nature of Man and society into the future – particularly during crisis situations. We should certainly be aware and open for new ideas in the context of radioactive waste management. But these ideas must stand up and be tested in a critical and pragmatic debate and with care to avoid typologies or simple conclusions by analogy. The present conceptions of socially controlled long-term surface facilities do not stand the test, nor even comparative analysis as suggested by Lakato or Popper; for this reason such ideas must clearly be refuted today. In this context it may be interesting to come back to reflections of thinkers such as Voltaire, who showed in his "Candide"[34] where paradisiacal or apocalyptic visions of the world through simple ideological glasses might lead. We are not in the best of the worlds of Leibnitz's thoughts, nor in the abysses of freshly conjured (axes of) evil. So let us simply be pragmatic and do the work of Voltaire's gardener, thus coming as close as possible to realizable concepts and projects for nuclear waste management.

Marcos Buser is member of EKRA-Commission and President of the Control-Commission of Mont Terry Project

34 Voltaire (1966): Candide, roman et contes, GF Flammarion, see too Ziolkowski Theodore (2000): The Sin of Knowledge, Ancient Themes and Modern Variations, Princeton University Press, Princeton and Oxford, p. 75-82

Table 1. **Discussed options of nuclear waste management through the decades in available literature**

	HLW/TRU	**LLW/ILW**
Dispersal	*Dispersal in oceans under special conditions (Glueckauf, 1955)*	*Releases in air and water (different authors, since end of 40ths)*
Partial Containment	*Disposal in deserts or special zones (Glueckauf, 1955)* International prohibited areas (WHO 1956)	*Sea-dumping in canisters or drums (different authors, since end of 40ths)* *Continental disposal (different authors, since end of 40ths)* *Burial of wastes (different authors, since end of 40ths)* *Seepage of liquid waste-streams in pits, trenches, cribs, ponds, basins (different authors, since end of 40ths)* *Injection in wells (different authors, since end of 40ths)* *Grout injection (ORNL, 1966)*
Containment	Controlled long-term storage for indefinite periods of time – "Mausoleums" (Forrest 1948) *Calcination / vitrification / ceramics, etc. (different authors, since ends of 40ths)* *Disposal in deep geological formations (different authors, since early 50ths)* *Sub-seabed disposal (Evans 1952)* *Oceanic trenches (Renn, 1955)* *Disposal in Antarctica ice (Philbert, 1959)*	Controlled long-term storage (different authors) *Disposal in caverns (different authors, since 50ths)*
Others	**Transmutation (HLW)** **Space (HLW)**	

Italic: strategies based on passive safety measures

Bold: special options relying on exceptional technical applications

Other: strategies based on active participation of society

Table 2 **Rate of change for typical events in nature**

	Subsystem	Event	Speed of movement (approx.)			Relationship (factor)
"Uninhabited" nature	Air	Zephyr	1 km/h	0.3 m/s		10^{6}
		Storm	150 km/h	40 m/s		10^{8}
	Surface water	Torrent		1 m/s		$3·10^{6}$
		River (e.g. Amazon)		0.1 m/s		$3·10^{5}$
	Groundwater	Flow velocity, for example in the gravels of a river valley or along a fast flowpath in fractured rock (Molasse)		> $1·10^{-5}$ m/s	> 3 m/day	30
		Flow velocity in fine-grained sediments		$3·10^{-7}$ m/s	10 m/day	1
		Diffusion in clays		<$3·10^{-10}$ m/s	< 1 cm/year	< 10^{-3}
	Lithosphere	Plate tectonics, orogeny		$3·10^{-10}$ m/s	1 cm/year	10^{-3}
		Isostatic movements (Alps)		$3·10^{-11}$ m/s	1mm/year	10^{-4}
		Erosion (Alps)		$3·10^{-11}$ m/s	1 mm/year	10^{-4}
Inhabited world	Biosphere	Worms in earth		$1.5·10^{-4}$ m/s	1 cm/min	$5·10^{2}$
		Fish in water		0.1 – 1 m/s		$3·10^{5}$ - $3·10^{6}$
		Bird flight	50 – 300 km/h	10 – 80 m/s		$3·10^{7}$ - $2·10^{8}$
	Human	Walking	4 km/h	1 m/s		$3·10^{6}$
		Cycling	40 km/h	10 m/s		$3·10^{7}$
		Car	100 km/h	25 m/s		10^{8}
		Flying	800 km/h	220 m/s		10^{9}

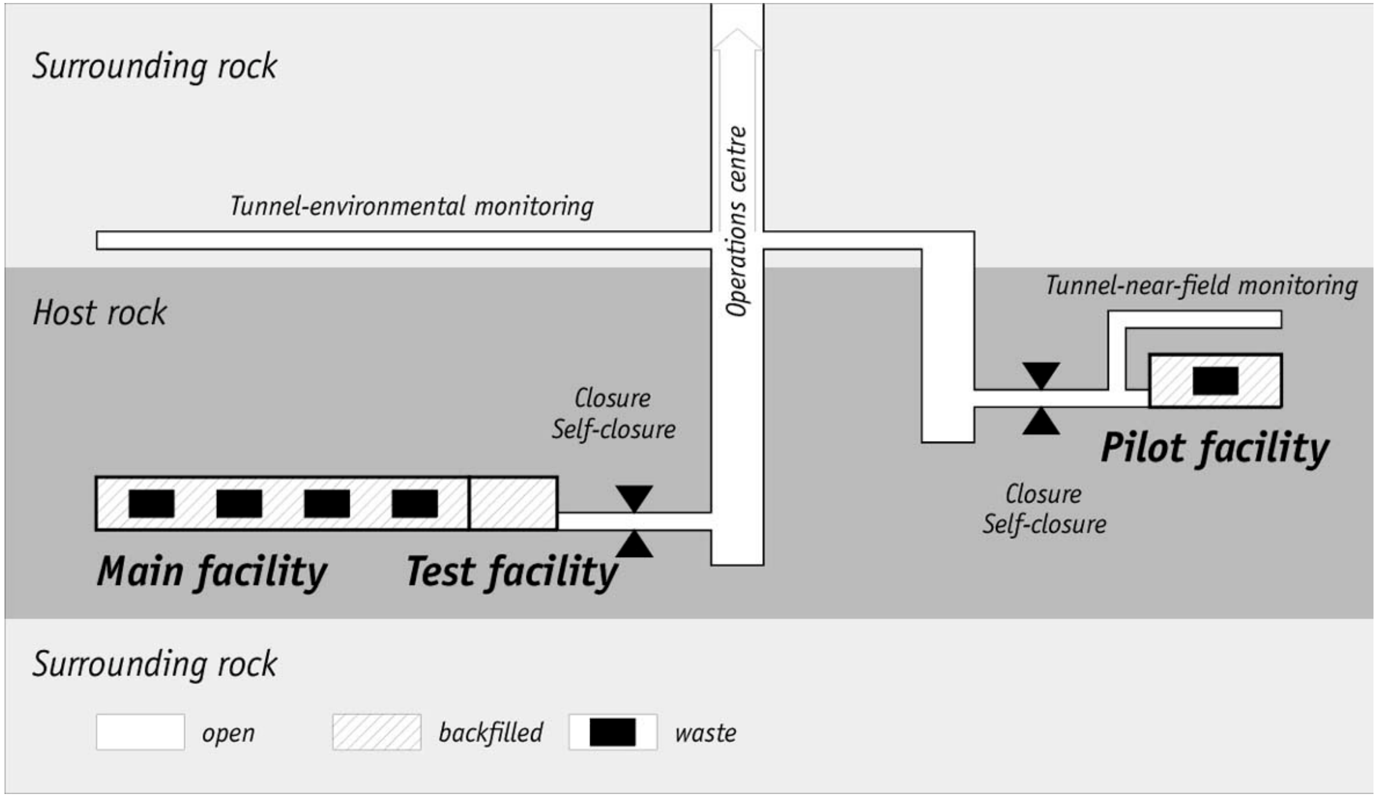
Table 3. **Predictability in time of natural and social events**

Events		**Period of prediction**							
		Minutes to hours	Hours to days	Days to weeks	Weeks to months	Years to decades	Decades to centuries	1 000 yrs. to 100 000 yrs.	100 000 yrs. and more.
Natural events	Global climatic evolution	Predictability high					Trends recognisable ?	Uncertain to speculative	
	Weather prediction	Predictability high to average			Uncertain to speculative				
	Earthquake magnitude in various risk zones	Predictability high						Relatively high	Average to uncertain
	Time of occurrence o an earthquake	Predictability average to low			Uncertain	Speculative			
	Groundwater circulation at specific locations (deep groundwater)	Predictability high						Average	Trends recognisa-ble to speculative
	Impact of an comet the size of the Arizona meteorite	Predictability high					Relatively high	Average to uncertain	Speculative
Social events	Possibility of changes in the European political system	Predictability high				Average to uncertain	Speculative		
	Tendencies in development of new technologies	Predictability high				Average to uncertain	Speculative		
	Tendencies in development of pardigms (political, ideological, religious)	Predictability high				Average to uncertain	Speculative		

Table 4. **Events in past societal development and possible future events in waste disposal**

Future event	time (years) **start at year 2000**		Event in the past
End of functioning of drainage systems of a conventional waste disposal site (reactive waste site in Swiss TVA classification)	100	-100	• Technology: first off-shore drilling in search of hydrocarbons • Physics: beginning of quantum theory • Biology: rediscovery of the experiments of Gregor Mendel • Philosophy: death of Friedrich Nietzsche • History: Evans discovers the palace of Knossos (Minoan culture, Crete)
Time-span of risk evaluation of a conventional waste disposal site (example of municipal waste dump of Riet, Winterthur)	200	-200	• Technology: electrolysis with galvanic battery (Nicholson/Carlysle) • Physics: W. Herschel discovers infrared radiation • Medicine: first use of chlorine to disinfect water (W. Cruikshank) • History: directorate (consulate) of Napoleon (1799-1804)
Probable end of functioning of engineered barriers of a conventional waste disposal site (reactive waste site in Swiss TVA classification, locations of Oberholz, Suhr AG and Feldmoos, Niederhasli ZH)	400	-400	• Technology: construction of a first armored warship by the Korean admiral Vinsunsin • Physics: William Gilbert claims that the earth is a spherical magnet • History: Giordano Bruno is burned to death in Rome
Radiation protection criteria for disposal sites for short-lived LLW fulfilled	500	-500	• Technology: Leonardo da Vinci develops the concept of the helicopter • History: Cabral discovers Brazil (Porto Seguro)
End of functioning of engineered barriers of a conventional waste disposal site (reactive waste site in Swiss TVA classification, locations of Oberholz, Suhr AG and Feldmoos, Niederhasli ZH)	800	-800	• Technology: new generation of mills developed by Cistercian monks • Mathematics: introduction of number 0 by Chinese mathematicians • Philosophy: death of Averroes • History: preparation for 4th crusade
Ion-exchange capacity of underground environment exhausted for the compartment for reactive wastes (example: waste disposal site of Feldmoos)	2,500	-2,500	• Technology: production of steel (India) • Mathematics: death of Greek philosopher Pythagoras • Geology: Greek philosopher Xenophanes of Kolophon describes fossils (Fragment 5) • History: Greek-Persian wars (Marathon, Xerxes etc.)
Ion-exchange capacity of underground environment exhausted for the compartment for inert wastes (example: waste disposal site of Feldmoos)	30,000	-30,000	• Upper Paleolithic: uses of line marks (groups of 5) for counting (cattle)
Time-span of isolation needed for HLW repository, orders of magnitude	100,000 until 10E6	-100,000 until -10E6	
Isolation time-span for an underground disposal site for industrial chemical wastes (e.g. salt mine of Herfa-Neurode, Germany)	?	-?	

Figure 1 **The underground facilities in the "monitored, long-term geological disposal" concept of EKRA**



LONG TERM INTERIM STORAGE: AN EMERGING APPROACH FOR WASTE MANAGEMENT POLICY IN FRANCE

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SUMMARY

Which waste?

In France, the low and medium level short lived radioactive wastes are disposed of in a surface repository in the north east of the country. It is the Aube disposal centre run by Andra. Its capacity is about 10^6 m^3, which allows disposal operations beyond 2020.

The long-lived waste will represent, in 2020, 50 10^3 m^3 of Intermediate Level waste (<10% of the total activity) and 5 10^3 m^3 of High Level waste (>90%) of the total activity. Most of them are well packaged: vitrified waste, compacted, bitumised and cemented waste.

Up to 1990, the reference solution for those waste was a deep geological disposal (DGD). The concept of DGD is based on fully passive safety as the deep geological layer provides:

- protection of the packages against corrosion
- a limitation of the risk of external aggression (human intrusion, climatic or tectonic hazards)
- a large delay on the migration of the nuclides back to the surface so that it does not occur before the radioactivity has almost fully disappeared.

In 1990, the French Government decreed a moratorium on the creation of deep geological repository. Then a law has been issued asking for exploring new ways of management of radwaste: Partitioning & Transmutation and Long Term Interim Storage (LTIS).

Long term storage

LTIS was first raised as an answer to the questions: "Why should we move the waste from their present industrial storage? Can this situation last a long time?"

The present industrial storage facilities do not raise safety concerns. They require close surveillance and maintenance. Successive refurbishing can clearly extend their lifetime.

Nevertheless, CEA has developed special concepts for facilities able to last a century or more. Such facilities could be built in case of full reinstallation of the waste, change of juridical status (relocation). A need of special LTIS can also come from new requirements on safety standards (e.g. subsurface to avoid hazards coming from plane crash or missile).

The main principles guiding the conception of a LTIS are very similar to those of industrial storage facilities with a particular emphasis on long lifetime, thus passivity and robustness. The confinement of the waste must be guaranteed permanently. The packages must remain clean, strong and movable at any time. This means a special care on corrosion and on maintenance.

The long term perspective raises some juridical problems: "Who is running the facility?" There is an almost 100% risk of disappearance of the facility owner. Provision must be made to guaranty the existence of a relaying institution.

A LTIS could be chosen for some kind of waste or for all waste, because the society does not want to make an immediate decision on a permanent management policy. Providing a large cooling time brings some clear benefit for HLLLW. And, finally, the society may bet on important scientific improvements which would modify the radioactive waste landscape. However, on may argue that waiting is not a responsible attitude towards future generations.

It should be emphasised that any decision on LTIS requires a strong and conscious commitment by the society as such a facility must be always watched and maintained rigorously until it is emptied.

Special attention must be provided to avoid that a LTIS transforms itself surreptitiously into a bad disposal.

The logic of intergenerational responsibility requires that some financial provision be made for long-term maintenance and final operation.

Conclusions

In conclusion, it appears that there is no clear technical limits to the duration of LTIS provided some conditions are respected.

Such a solution should be offered to the society as an alternative to deep geological disposal.

But, the society must remain aware of the permanent collective responsibility and thus, of the commitment that is required when deciding (or prolonging as well) a LTIS.