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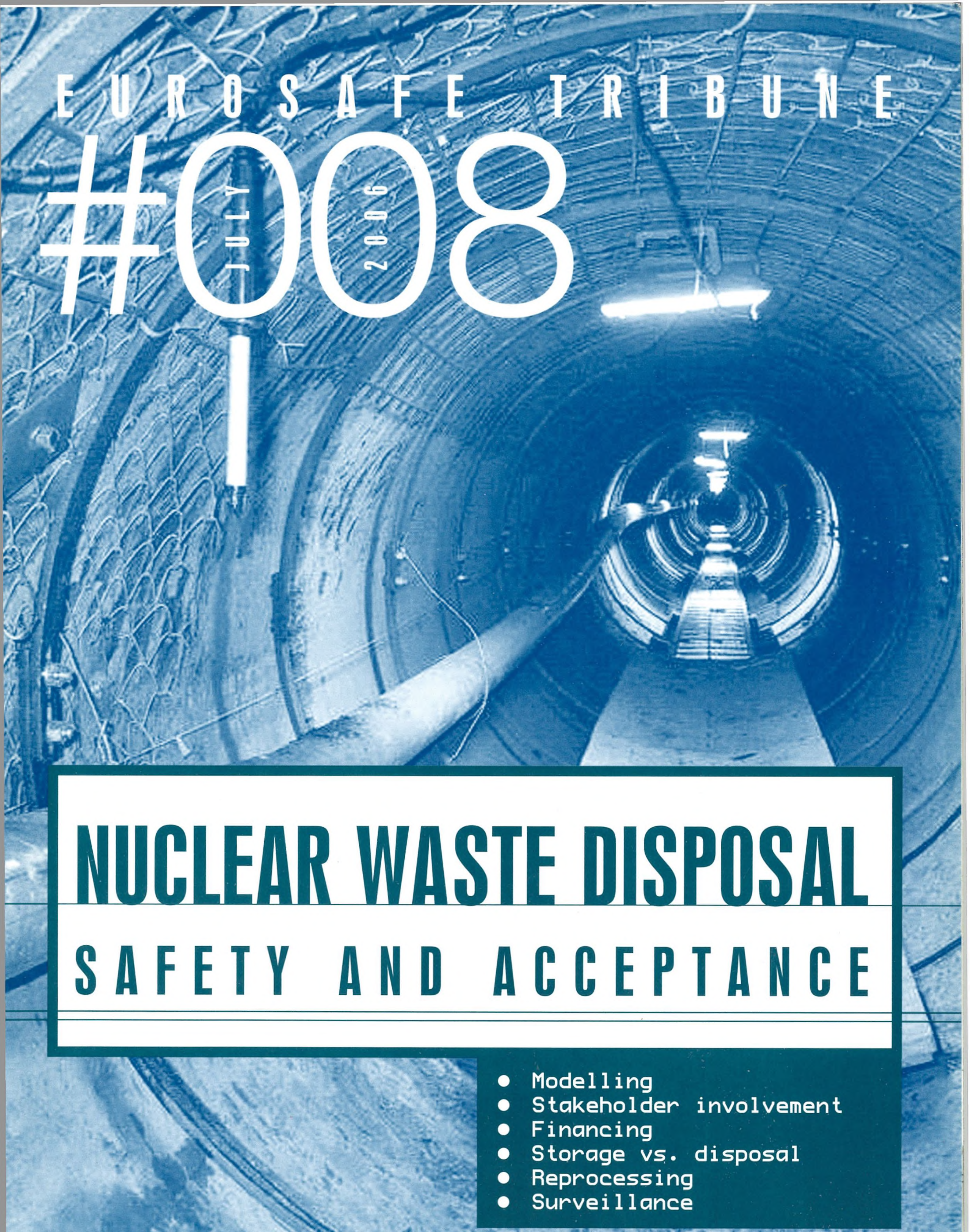

NUCLEAR WASTE DISPOSAL

SAFETY AND ACCEPTANCE

- Modelling
- Stakeholder involvement
- Financing
- Storage vs. disposal
- Reprocessing
- Surveillance

TO OUR READERS

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Jacques Repussard and Lothar Hahn

Adding to the quantities of high-level, medium-level and low-level waste generated every year almost exclusively by nuclear fuel cycle activities world-wide, the eventual dismantling of the nuclear power reactors and fuel cycle facilities will result in ever larger amounts of waste, making the processing, storage and disposal operations – far beyond the technical or industrial aspects of the problem – first and foremost a challenging social issue, today and in the future.

For the time being, no geological disposal facility for high-level, long-lived radioactive waste exists, and SKB [1] expert Saida Laârouchi Engström expects 40-50 more years at least to be necessary for carrying out all measures needed to dispose of such waste in a safe manner. On the other hand, partitioning and transmutation techniques aimed at changing long-lived radionuclides into isotopes with shorter half-lives are being investigated, e.g. in France and Germany, but these require highly developed processing of the waste in order to separate the long-lived radionuclides and special types of nuclear reactors where they would be transmuted…

So, where do we stand: are present waste packaging techniques to be optimised? Are storage and geological disposal antagonistic or complementary options of a radioactive waste management strategy? Should concepts of reversibility and retrievability be incorporated in waste disposal programmes? Are financial resources secured to ensure safe operation and continued surveillance over the long term? How should the models used for assessing the possible future behaviour of repositories be dealt with from a safety perspective, as they are based on calculations which inevitably contain a certain degree of uncertainty?

These questions and many others are raised and debated, in the present issue of the Eurosafe Tribune, by specialists – safety authorities, technical safety assessment organisations, operators, research organisations, etc. – involved in the management of nuclear waste. ●

[1] Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Co), see. article on p. 4

STAKEHOLDER INVOLVEMENT IN SITING A SPENT-FUEL REPOSITORY:
WHEN SCIENCE MEETS DEMOCRACY

By Saida Laârouchi Engström,
Head of Environmental Impact Assessment (EIA) and Public Information, Swedish Nuclear Fuel and Waste Management Co. (SKB)

■ Stakeholder involvement at each step of a siting process of a repository for radioactive waste is necessary, difficult and time-consuming. To make it rewarding, a few key aspects have to be given deep consideration, such as: meeting in a respectful and serious way all emotions that may arise from a deep repository project; taking time and effort to provide knowledge and understanding of all different aspects of the project; allowing for the development of science and technology to reassess the project periodically, and... building trust based on the increased direct participation of citizens in the decision-making process. A Swedish perspective is provided below.

Saida Laârouchi Engström
Head of EIA and
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Repository projects: the soundness of a "keep the door open" policy

In Sweden, a general policy is that nuclear waste produced inside the country must also be disposed of inside the country. In this purpose, money for the activities is set aside in a special reserve fund via a charge based on the electricity production from the nuclear power plants. The four Swedish utilities have jointly formed the Swedish Nuclear Fuel and Waste Management Company (Svensk Kärnbränslehantering AB, SKB), whose task is to plan, construct, own and operate the systems and facilities necessary for radioactive waste transportation, interim storage and final disposal. On their side:

- the Swedish Nuclear Power Inspectorate (Statens Kärnkraftinspektion, SKI) and the Swedish Radiation Protection Institute (Statens Strålskydds-Institut, SSI) review SKB's proposals to make sure they meet the requirements on safety and radiation protection;
- the government issues permits and licenses for siting, construction and operation;
- the municipalities where new facilities are to be built must approve the site selection.

It will take at least 40-50 years to carry out all measures needed to dispose of all long-lived and high-level nuclear waste in a safe manner. It is, therefore, appropriate to proceed in steps and keep the door open for technological development, changes and possibilities for retrieving already deposited waste. This will ensure freedom of choice for the future while at the same time demonstrating the deep disposal method on a full scale and under actual conditions. Decisions regarding site selection, construction and operation of an encapsulation plant and a deep repository will also be taken in steps and based on progressively more detailed information.

> Social and political aspects: dealing with contradictions

The siting process for a repository of spent nuclear fuel encompasses three steps: general siting studies, feasibility studies and site investigations. Stakeholder involvement at all levels is time-consuming but also very rewarding. It is very important before one engages in a dialog with the stakeholders to have a well defined project, clear role distribution and responsibilities among key players and of course a good financing system.

SKB has got approval in the year 2000 to perform site investigations in the municipalities of Oskarshamn and Östhammar. The approval has been preceded by a decision in each municipality council taken by the elected representatives. The decisions were positive to site investigations in these communities with very large majorities. Several experiences have been gained since the siting process started late 1992. Somewhat provocatively, there are two opposite views on a deep repository:

- In one perspective, it is perceived as a safe environmental facility of importance to everyone, where the nuclear waste is isolated so that people in the future will be protected. It is based on long-term planning and stringent quality standards. It provides good jobs with advanced technology, attracts positive interest both in Sweden and internationally, and contributes in many ways to the positive development of the municipality and the region.
- In another perspective, the deep repository is an atomic waste dump and a threat to the environment and the future. This arouses anxiety and fear among the population. The general attitude towards the municipality and the region will be negative, visitors will stay away and the region's economic development will be adversely affected.

The perceptions and sometime passionate attitudes of the public have to be met in an open and honest way. To most people, the siting of a deep repository is a very special project and many of those potentially affected by the project will feel deeply engaged in the issue.

> People trust other people rather than concepts or organisations

Based on the above, SKB has launched extensive consultations with the stakeholders (politicians, local decision makers, public authorities, environmental organisations...) which include just about every individual or organisation with an interest in discussing the environmental impact of a final repository with SKB to contribute to prepare a sound environmental impact statement (EIS) in the near future. With a view to enabling the →

"Prior to engaging in a dialog with the stakeholders, it is important to have a well defined project, clear role distribution and responsibilities among key players and of course a good financing system."

→ international NGOs and the municipalities concerned to participate, the government has set a financing procedure for their needs to get involved through the dedicated funds for nuclear waste management. The environmental impact assessment (EIA) consultations started in the year 2003 and will go on until an application to construct the repository is submitted to the government which is planned to happen in the year 2008. Interacting with stakeholders requires substantial efforts and one of the difficulties is actually that the public find it uneasy to engage fully in a project that is taking a long time to reach the licensing and operation phase. Hence being creative on the format for the meetings and different events around the project is important to keep the dialog alive between the company in charge of spent-fuel management and all the stakeholders in the siting of a final repository. However small meetings seem to be more efficient than large ones and a face- to-face discussion between the industry and different stakeholders has proven to be outstanding in trust-building. People trust other people rather than concepts or organisations! ■

Key aspects to the sound management of a siting process

- ***Facts and emotions***

The project must consider all facts but also all emotions that may arise. They are as real as the facts and they have to be met in a respectful and serious way. The dialogue with the public has to be open and should rather focus on why the project is planned than on providing a lot of technical details.

- ***Time***

To most people, radioactive waste and the concept of geological disposal is not easy to comprehend and it will take time and effort to provide knowledge and understanding of all different aspects of a deep repository project. Thus there is a need to show patience. Changing attitudes and building confidence simply takes time.

- ***Flexibility***

Science and technology is in a state of rapid development. Social values and community values also develop with time. It is important to be flexible so that the concept can accommodate these changes. The concept should be adapted to stepwise development where new information can be incorporated at each development step. This is in line with the environmental and ethical bases for geological disposal, namely that stepwise implementation of plans for geological disposal leaves open the possibility of adaptation, in the light of scientific progress and social acceptability, over several decades, and does not exclude the possibility that other options could be developed at a later stage.

- ***Democracy***

An ongoing social change is that citizens, more and more, directly participate in the decision-making process. This is a development of democracy that should be shown full respect. There is no other road to success than to accept and support the democratic process. A national political decision will only be made possible after the technical, scientific, social and local political issues are solved. However, it should also be a responsibility of the national politicians to support the municipalities that try to find a suitable site for solving a national issue. The citizens will accept a repository if they find good reasons to say yes.

STORAGE vs. GEOLOGICAL DISPOSAL: THE ART OF DEALING WITH TIME

By Auguste Zurkinden,
Head of Division for Transport and Waste Management Safety, Swiss Federal Nuclear Safety Inspectorate (HSK)

If the only currently realistic option for the final step of the management of high-level and long-lived radioactive waste (HLW) is geological disposal, no facility for such waste is available at the moment, making interim storage for a few decades a necessity. Thus, far from being antagonistic options, storage and disposal complement each other. In certain circumstances, there are good reasons for long-term storage over 100 years or more. From regulatory requirements to public acceptance, this article reviews HLW management issues from a Swiss perspective.

Transmutation: a still remote prospect

Depending on the radionuclides contained, the radiological hazard represented by the waste may decrease rapidly with time or last over thousands and even millions of years. In this respect, HLW is most demanding in terms of safe management.

Theoretically, long-lived radionuclides can be changed to isotopes with shorter half-lives by means of transmutation, shortening the duration of the hazard represented by the corresponding waste. But this requires highly developed waste processing in order to separate the long-lived radionuclides as well as special types of nuclear reactors where these radionuclides would be transmuted. Transmutation remains therefore a remote prospect.

> Disposal: the preferred option, but not yet implemented

Since radioactivity cannot simply be removed, various options for the disposal of radioactive waste have been contemplated, for instance on or into the seabed, into subduction zones or into the Antarctic ice. All these options suffer from a lack of possibilities for control and monitoring. It has also been proposed to store the waste under permanent social control for an indefinite time. This would require very long-lasting stability of society, which cannot be taken for granted. Therefore, the preferred option for the final management of HLW is geological disposal, as stated by the Nuclear Energy Agency of the OECD.

No geological disposal facility for HLW is yet in operation. Thus storage of radioactive waste, especially HLW, →

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→ is currently a necessity. The questions which arise from that situation are notably: How long should radioactive waste be stored? What should the final destination of the waste be? Can long-term storage be considered as an end-point solution to the management of such kinds of waste? An insight into the Swiss situation is given below as an illustration.

> Interim storage: the need for continuous surveillance and maintenance

Containing radioactive waste in a facility for a limited period of time, *with the intention of retrieval,* is the purpose of interim storage. Since final disposal repositories are missing yet, interim storage is a necessary element of current strategies for the management of HLW. However, it has to be considered only as a temporary measure and cannot constitute an end-point solution to the management of these kinds of waste.
Interim storage should fulfil two main requirements. On the one hand, protection of the workers, the surrounding population and the environment must be ensured, not only under normal operation conditions but also in accidental situations. Some countries – for instance Switzerland – require that the consequences of an air crash be considered in the design of a storage facility for spent fuel or HLW. On the other hand, a storage facility has to be designed so that the waste packages are held and can be retrieved without any impairment. This implies monitoring and control of the ambient conditions (temperature, humidity, etc.) within the storage facility. Obviously, interim storage can be relied upon to provide safety as long as active surveillance and maintenance are ensured.
When located near the facilities where radioactive waste is produced, interim storage is not an issue of public concern, but this can be different in the case of a stand-alone central storage facility. In Switzerland, the Central Storage Facility for spent fuel and all kinds of radioactive waste operated by Zwischenlager Würenlingen AG (Zwilag) has been licensed and constructed without strong opposition from the local population. The shipments of spent fuel from the Swiss NPP and of vitrified high-level reprocessing waste from Cogema to the Zwilag facility take place as a matter of routine without demonstrations. In contrast, large demonstrations took place against shipments of spent fuel and high-level waste to the central storage facility at Gorleben (Germany). This was one of the reasons for the German Government to require the construction of decentralised storage facilities for spent fuel at the NPP sites.

> Long-term storage: a strong political and societal commitment

Different motivations may lead to the inclusion of long-term storage – i.e. *storage for about 100 years or more* – into a radioactive waste management strategy, e.g. the prospect of alternative technological solutions for the elimination of radioactive waste, the potential use of spent fuel or radioactive waste as an energy resource for the future, or other ethical, societal, political or economic reasons. Long-term storage does not constitute, however, an end-point of the management of HLW.
The two main requirements for interim storage – i.e. protection of human health and the environment and retrievability of the waste packages – must be fulfilled as well, but for much longer time periods. Long-term storage thus implies the capa-

bility to recognise when repackaging, replacement of equipment or store refurbishment is necessary as well as the ability to perform such operations. The organisational capability to continue surveillance and maintenance over the long term must be set up and the financial resources to ensure safe operation must be secured. For these reasons, any decision on long-term storage demands a strong political and societal commitment.

> Geological disposal: coping with uncertainty

In contrast to interim or long-term storage, geological disposal constitutes a final step in a waste management strategy, as it means the emplacement of radioactive waste in a facility constructed in an appropriate geological formation, *without the intention of retrieval* (even if this does not exclude retrievability). It is viewed by the IAEA as "*the preferred way to achieve the overall objective of radioactive waste management, i.e. to protect human health and the environment now and in the future without imposing undue burdens on future generations*".

Whereas storage implies active control in order to provide safety, the concept of geological disposal relies on passive safety functions. The natural and the engineered barriers of a closed disposal system must function without any human intervention, making active control after closure unnecessary. Again, this requirement does not exclude the possibility of continued monitoring after the closure of a repository.

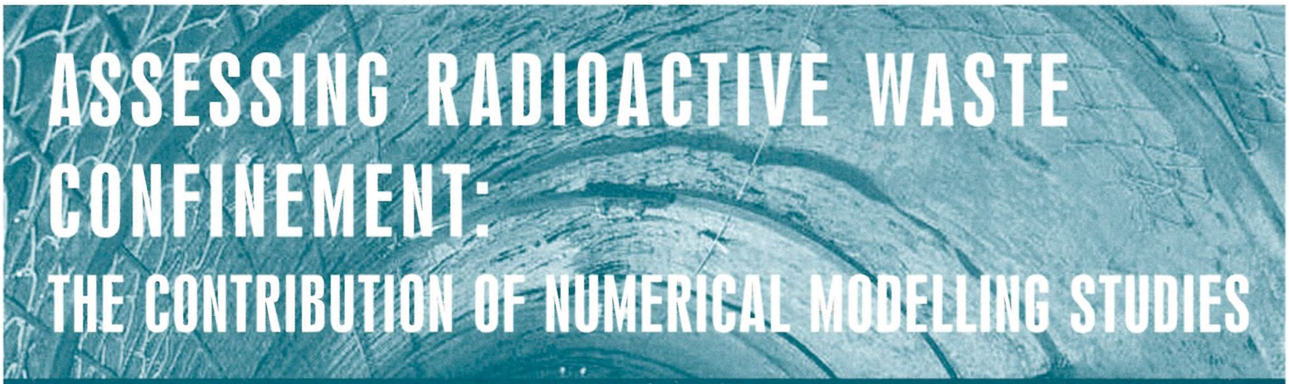
Since HLW represents a radiological hazard over periods of time up to a million years or more, safety assessments have to be based on models which describe the possible future behaviour of the repository system. Such calculations inevitably contain a degree of uncertainty: the further into the future calculations are made, the greater the uncertainty.

> A major stakeholder involvement issue

The very long time span to be taken into account is probably the main reason for a certain mistrust of geological disposal in the general public. Almost every country with projects for geological disposal has encountered opposition of the local population as soon as it became site specific. Several scientifically and technically sound repository projects – such as the Wellenberg project in Switzerland – had to be abandoned because of a lack of public acceptance.

In order to render the implementation of the waste management strategy possible up to its end-point, an involvement of the stakeholders is thus necessary at an early stage of the decision-making process. Epitomised by the *Forum on Stakeholder Confidence* initiative launched by the Radioactive Waste Management Committee of the NEA, a new dynamic of dialogue and decision-making emerged, characterised by a shift from the traditional "decide, announce and defend" model to one of "engage, interact and co-operate".

Switzerland applies this new principle: the social demands on control and retrievability have been taken into account in the legislation on nuclear energy which entered into force in February 2005. In the selection procedure for a disposal site, currently prepared by the competent authorities, stakeholder participation is largely accounted for. One can thus expect, or at least hope, that the disposal facilities for radioactive waste which are necessary for the safe final management in Switzerland will be realised within reasonable time frames. ■



ASSESSING RADIOACTIVE WASTE CONFINEMENT:
THE CONTRIBUTION OF NUMERICAL MODELLING STUDIES

By François Besnus and Christophe Serres,
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The long-term safety of radioactive waste repositories draws upon the "concentration and containment" strategy based on a multi-barrier system made of natural rock and an engineered barrier system (EBS). As design options must contribute to minimise disturbances caused by the repository in order to preserve confinement properties of the different components, IRSN carries out numerical modelling activities aimed, on the one hand, at quantifying physical processes and interactions possibly occurring in an underground repository and, on the other hand, at quantifying confinement capabilities of the different barriers. Two examples of such numerical modelling studies were presented by the authors at the Nucef [1] conference held in Tokaimura (Japan) on 9-10 February 2005.

What are engineered barriers?

In addition to the geologic isolation provided by the rock layers, engineered barrier systems consist of a variety of components such as the waste form, buffer, plugs, seals and backfill. Among main disturbances are chemical and mechanical interactions between different exogenous materials – cement, steel components, bentonite [2] –, host rock and disposal facilities that may cause damage to the host rock, the different barriers and the canisters. Another important issue for long-term safety is the feasibility of seals and plugs to close the repository in order to limit advective [3] water flux and mitigate possible by-pass of the host rock.

> Modelling: a contribution to the long-term safety assessment approach

IRSN performs numerical modelling studies for assessing geochemical interactions and the role of engineered barriers for the confinement of radionuclides. Among the numerical modelling activities performed, IRSN studies focus on the understanding of:

- transient processes as chemical and thermal interactions,
- dehydration/rehydration which occur at drilling phases and after closure of the repository,
- gas production and migration through the different components and long-term behaviour of the excavation disturbed zone (EDZ) in indurated clay.

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[1] Nuclear Fuel Cycle Safety Engineering Research Facility (Nucef).

[2] Bentonite is a material composed of clay minerals commonly used in drilling mud. Bentonite swells considerably when exposed to water, making it suitable for protecting formations from invasion by fluids.

[3] Advection refers to the predominant transport of solute by water flow.

New and high-performance numerical methods are also under implementation to improve resolution of coupled flow and transport equations for highly heterogeneous systems. This modelling strategy is part of a broader approach for assessing the long-term safety based on a stepwise process for building confidence in the confinement properties of a facility. This stepwise process relies on three distinct steps:

- assessment of the disturbances caused by the repository and their possible influence on the performance of each barrier,
- assessment of the contribution of confinement barriers and repository design to the overall safety of the repository for both normal and altered evolutions of the disposal,
- assessment of individual exposures possibly arising from radionuclides release and transfer to the biosphere.

The two examples below illustrate the ability of numerical calculations to contribute to the long-term safety assessment approach:

- In the first example, disturbances and interactions between cementitious materials, bentonite and clayey host rock are tackled by numerical calculations at process levels that allow addressing main issues of interest for performance assessment.
- The second example highlights the role played by bentonite engineered barriers, plugs and seals as hydraulic and migration barrier in presence of an excavation damaged zone around the vaults, drifts and shafts for different hydrogeological settings.

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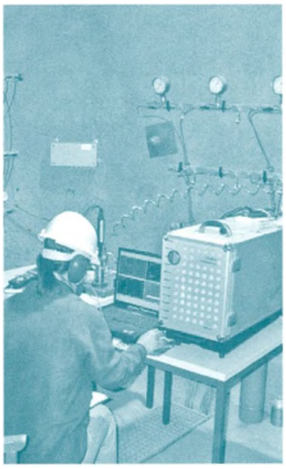
> Cement/clay interactions modelling: lessons learnt for performance assessment

Cement is often included in disposal design for purpose of handling and mechanical support. This material is chemically very different from bentonite and represents a potentially important source of perturbation. Reactive transport modelling was performed with a computer code (called HYTEC) so as to assess such chemical perturbations in the near-field. The simulations aimed at:

- identifying the main interaction processes and main modifications of the bentonite geochemistry;
- specifying the space and time scales of the perturbation;
- evaluating the consequences on radionuclide migration in terms of solubility limits and distribution coefficients.

The main lessons learnt for performance assessment based on these simulations are as follows:

- *Regarding the chemical buffer role of a bentonite plug,* when cement components surrounding the plug are considered, the alkaline perturbation is partly absorbed by mineralogical transformations occurring close to the interface. However, a bentonite barrier does not prevent a high-pH plume from reaching the waste packages' surface.
- *Regarding its chemical containment role,* bentonite provides favourable retention properties for a wide range of radionuclides. In the presence of cement, though geochemical perturbations are marked, no significant change of bentonite retention properties has been shown by calculation for a given set of radionuclides such as uranium, technetium, neptunium, radium or caesium. But these results must be taken with caution regarding the lack of data available at 70C° for sorption (except for caesium and radium) and solubility limit (except for technetium). So, even if it appears that ➔



Gas chromatography

→ alkaline plume should have only a minor influence on the bentonite containment properties for the radionuclides investigated, performance assessment should be completed by further analyses.

> Assessing the role of engineered barriers in the near field

In addition to the studies devoted to cement/clay interactions, IRSN assessed the role of bentonite buffers and seals in preventing and limiting radionuclide migration. A computer code called MELODIE was used to simulate the flow and transport of radionuclides. Three situations were investigated regarding three hydraulic cases:

- the expected evolution of the repository when all bentonite seals are efficient ("reference" case),
- a bypass via the EDZ of all seals in the drift ("badly sealed" case),
- the absence of seals ("no seal" case).

The following lessons can be drawn:

- *Role of seals*: when seals are effective ("reference" case), handling drifts and shafts play no specific role in the transport of radionuclides and diffusive transport regime occurs through the facility. But, if seals are bypassed by EDZ ("badly sealed" case), an influence of enhanced transport of activity through EDZ can be noted by earlier and higher released fluxes. For the "no seal" case, the shapes of activity flux curves are characteristic of an advective dominated regime through handling drifts and shafts which constitute a fast pathway for all radionuclides.
- *Role of bentonite buffer*: the "no seal" case has been assessed as being the worst "hydraulic" case investigated in this study. In this case, sorption in the bentonite buffer delays the migration of radionuclides released from the waste packages towards the backfill and the EDZ for a limited period of time (less than 10,000 years for Cesium 135). The sorption efficiency of the bentonite buffer is enhanced for medium-life radionuclides that decay during transfer and in some cases prevents the solubility limit to be reached.
- *Role of host rock*: when seals are effective ("reference" case), the host rock is the main diffusive pathway and clay delays and spreads the amount of activity. Even for the "no seal" case, the host rock still contributes to reduce the amount of sorbed radionuclides able to reach the shaft (by a factor of 10 for Cesium 135) because of the high sorption capacities all along the handling drift. In this case, the host rock acts as a "sink" for sorbed radionuclides.

> Long-term performance assessment of bentonite EBS

From the complementary modelling studies described above, the following lessons can be drawn:

- As seals are essential to ensure a diffusive regime in all the facility, sealing capabilities must be justified and design options must preserve bentonite seals from alteration.
- Bentonite buffer does not play a significant role on the migration of non-sorbed and soluble radionuclides. For the sorbed radionuclides, retardation due to chemical properties of bentonite buffer has to be compared to the retardation provided by the favourable "sink" effect due to retention properties of the host rock.

As a consequence, the choice of bentonite buffer around the canisters has to be justified on the basis of the assets it can provide in comparison with the drawbacks it may cause. ■

NUCLEAR SPENT-FUEL MANAGEMENT: CONTRIBUTING TO A SUSTAINABLE ENERGY POLICY

By Philippe Garderet,
Scientific Vice President, Areva, France

The fleet of nuclear plants in operation throughout the world produces 10,000 tons of spent fuel per year. Among them, 6,000 tons per year are unloaded from the 350 light water reactors in use (2,000 tons per year in the US and 1,100 tons per year in France). In this context, minimising the quantities of ultimate waste, re-using what has an energetic value (according to available technologies and the current economic context), and optimising consumption of natural fissile resources are the goals of an "integrated management of resources" according to sustainable development requirements. In this respect, some basics of a long-term, closed-cycle policy in terms of economy, natural resources management, environmental impact, costs and non proliferation are recalled below.

Spent-fuel management results from national "sovereign" policies: it may be considered as waste meant for direct disposal (Finland, Sweden, US up to now) or as re-usable material fit for reprocessing (France, Germany, Japan, Russia, UK…).

Spent-fuel reprocessing and recycling is now part of industrial services and, even if the business is strictly framed by national and international rules, there is an international market *via* commercial contracts. The choice of the utilities may depend on various considerations such as:

- size and age of the existing nuclear fleet (as it is necessary to have the capacity to optimise recycling),
- price, reliability and quality of the fuel provider,
- real benchmarking with the competitive option of direct disposal (now not industrially operated),
- a legislation and regulation frame at a national level giving sufficient visibility,
- links with an energy policy: place of nuclear in the actual and future energy mix, forecast of energy prices (gas, Uranium…).

> Using less raw fissile material and disposing less waste: a sustainable philosophy

In a long-term analysis, spent-fuel processing may be considered as a requirement for developing the use of nuclear energy. Burning only the 0.7% of Uranium 235 contained in natural uranium may be regarded, in this respect, as an obviously non-sustainable attitude. Therefore, most of the conceptual designs positively analysed in the GenIV forum are closed-cycle systems aimed at converting Uranium 235 into plutonium recyclable in fast-breeder reactors.

Besides optimising the use of ➔

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→ fissile material, the second goal of the closed cycle is to minimise the quantities of ultimate waste. Roughly speaking, the technology available for conditioning spent fuel in view of direct disposal leads to a waste volume at least 5 to 10 times the volume now achievable after processing, i.e. more than 2 m^3 vs. less than 0.4 m^3 per ton of heavy metal. For countries operating or building a large fleet of nuclear plants, such consideration about the volume of waste to be disposed of in deep repositories is of utmost importance. The ongoing long debate about the optimisation of the final disposal at Yucca Mountain played a major role in the growing interest of the USA in reprocessing technologies.

In many ways, spent-fuel reprocessing appears as the most virtuous waste management option, as it allows immediate conditioning, volume reduction, toxicity reduction and flexibility in scheduling the construction and operation of deep disposal facilities.

> A difficult cost comparison, but significant long-term benefits

Although the fuel cycle (front end + back end) accounts for less than 20% of the total production cost of nuclear power, its sound management calls for detailed cost evaluations based on a clearly defined methodology and perimeter ranging from uranium mining to final disposal of ultimate waste. Performed by both French and international panels, different studies all conclude that economical arguments cannot be sufficient with the currently available data and limited industrial experience to justify one or the other option. However, it can be easily inferred from all these studies that the slight a ditional cost [1] induced by reprocessing + recycling is largely compensated for by significant long-term benefits:

- minimised risk of underestimating the real costs of final disposal,
- minimised impact of future increase in uranium prices,
- a clear choice in favour of sustainable development: lower consumption of natural resources, minimised ultimate waste both in quantity and in toxicity conducive to a lower environmental impact for final disposal.

> A steadily decreasing environmental impact

Modern industrial facilities for spent-fuel reprocessing and recycling were designed, built and are now operated according to the ALARA ("as low as reasonably achievable") principle aimed at minimising both the radiological exposure of workers and radioactive releases into the biosphere. The impact of the radioactive releases at Areva's La Hague reprocessing complex are thus kept below 0.1 millisievert per year (i.e. well below the European regulatory limit for the public). In 2000, Areva NC (previously Cogema) committed itself to keeping the dose for the public below 0.03 millisievert per year, i.e. 1/100th of natural radioactivity, regardless of the industrial programme of processing activities to be performed on the site. This plant management is satisfactory from

[1] In France, the additional cost resulting from spent-fuel reprocessing+recycling is estimated around 10 €/yr for a family with an annual consumption of 8,000 kWh. By comparison, the management of domestic refuse costs the same family about 100 €/yr.

a radiological protection perspective and was acknowledged in the conclusion of a study conducted by the OECD/NEA. Moreover, the report of the MARINA 2 survey published by the European Commission in 2002 on the radioactive releases in the North Atlantic showed a constant decrease in the region over the past 25 years.

> Non proliferation: a matter of efficiency of the institutional system

At any step of the nuclear fuel cycle, and from the design of facilities through to industrial operation, theft and malevolent use of fissile material must be considered and brought appropriate response in terms of security. Examining the robustness of the fuel cycle towards such risk encompasses various aspects, e.g.:

- attractiveness of the material for weapon-making purposes by comparison to other sources,
- accessibility of the material regarding its physical state and the protection in place,
- efficiency of the measures implemented to control the use of the material.

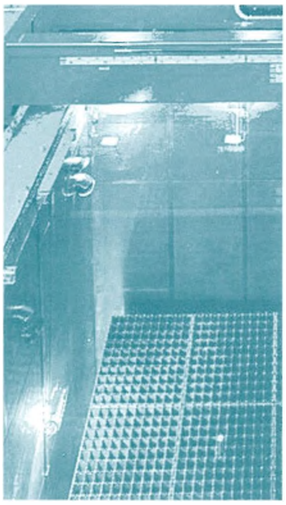
No substantial discrepancy between reprocessing and direct storage results today from a comparative security analysis. However:

- thanks to the enforcement of strict procedures in day-to-day operations, spent-fuel reprocessing and recycling has been operated industrially for 30 years without any hostile attempt of any kind reported. The low attractiveness of the material, the efficiency of the physical protection and the quality of the control system contribute to protect the plutonium extracted through spent-fuel reprocessing.
- In the direct storage option, the attractiveness of the plutonium contained in the spent fuel increases conversely to the decrease of the fission products' radioactivity. After 200 years, the dose rate will become negligible enough not to prevent any hostile attempt to retrieve the spent fuel with a view to recovering the contained plutonium.

In any case, the efficiency of the institutional system is pivotal, whatever option may be chosen for the back end of the nuclear fuel cycle. In that sense, the Euratom control laboratory hosted in the La Hague reprocessing complex provides a major contribution to nuclear security.

> Future prospects: a resurgent interest in spent-fuel reprocessing

As shown by French experience, closing the nuclear fuel cycle through spent-fuel reprocessing and recycling is regarded as a relevant long-term option for the sustainable development of nuclear energy, as it provides industrially proven solutions for optimising the management of natural fissile resources and of nuclear waste. Following the way opened by the international consensus about GenIV technologies, the recent evolution of the American position on spent-fuel reprocessing confirms this general trend. ■



Spent-fuel storage pool

RADIOACTIVE WASTE UNFIT FOR SURFACE DISPOSAL: GENERAL CONDITIONING PRINCIPLES

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The waste unfit for surface disposal is to be either placed in long-term storage facilities or disposed of in deep repositories. Given the current absence of precise acceptance criteria for either option, conditioning the waste consists of designing a primary confinement barrier (package) that is effective in various environment conditions, reduces the need for active safety systems and provides safety margins in case of a loss of one or several safety functions of the facilities. The authors provide below some principles for conditioning waste accordingly [1].

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Waste package design: achieving a high level of intrinsic safety

Radioactive waste conditioning consists of successive transformation steps aimed at confining radionuclides and minimising the difficulties associated with the design and operation of the storage and disposal facilities that are due to receive them. The nature and characteristics of the waste packages should be selected with a view to achieving a high level of intrinsic safety, thus facilitating the risk management of all the operations required before final disposal.

The technical options governing the placement of waste unfit for disposal in surface facilities in long-term storage facilities or their elimination in deep repositories have not yet definitely been chosen. Given today's absence of precise acceptance criteria, there is a strong added value for safety in designing waste packages reaching a high level of confinement that can be sustained over a long period of time in a variety of storage and disposal conditions.

The robust performance of the packages leaves room for different technical options concerning the future reception installations and provides safety margins against the uncertainties linked with long-term

[1] Original lecture given at the ICEM'05 conference in Glasgow (September 2005)

evolutions. The possibility of keeping some extent of reversibility of conditioning has to be taken into account if a trustworthy demonstration of package robustness cannot be provided *a priori*.

> Major design requirements for the storage phase

One of the basic principles for the design of an intrinsically safe nuclear waste package is that it should be physically and chemically inert. This characteristic can be defined in terms of properties to be reached as far as achievable. For the storage phase, the design of the nuclear waste packages should be focused on the following properties:

- low chemical reactivity with the environment (corrosion, oxidation in air, etc.) in order to limit package degradation and to ensure in any case that it can be retrieved from the facility;
- absence of significant inner physical and chemical modification in the storage conditions (e.g. crystallisation, fractionation, creeping…) to preserve its long-term confinement properties;
- low gas generation (radiolysis, chemical evolution, corrosion) to prevent package degradation through pressure or explosion hazard;
- low inflammability to reduce fire propagation or explosion (attention should be paid to the various possibility of initiation of these events in the installations);
- capability to minimise dispersion of radioactive material in incidental or accidental situations (e.g. package drop, flooding…), it is always favourable if the waste can be rendered non-dispersible;
- sufficient mechanical strength (e.g. long-term stacking…);
- prevention of criticality in any situation;
- thermal characteristics compatible with the use of passive ventilation systems to slow down package degradation in the event of a cooling system failure.

Drawing upon those principles, it is necessary to define both:

- the important parameters to be guaranteed in order to ensure that the aforementioned properties can be reached and sustained;
- the good practices to be implemented during package fabrication.

> Favourable properties for final disposal

Package properties likely to meet the safety requirements of a deep repository cover at least those described above for the storage facility. In particular, the packages should keep a good level of performance in various cases while the facility is still operated, thus their retrieval can be guaranteed at all time during the operational phase. In addition to these, their design should also take long-term post-closure safety into account. Confining the radionuclides through conditioning should therefore be performed in the two following ways:

- complete isolation of the waste from the environment during a given period (a performance that can mainly be reached by use of a metal container),
- limitation of the radionuclide release once the container is degraded (the presence of a confinement matrix slows the release).

In order to meet these two confinement objectives, the waste package properties could be determined after addressing a series of specific issues:

- the isolation of the waste should be ensured by a long-lasting envelope; →

Experiments on the qualification of backfill material in repositories

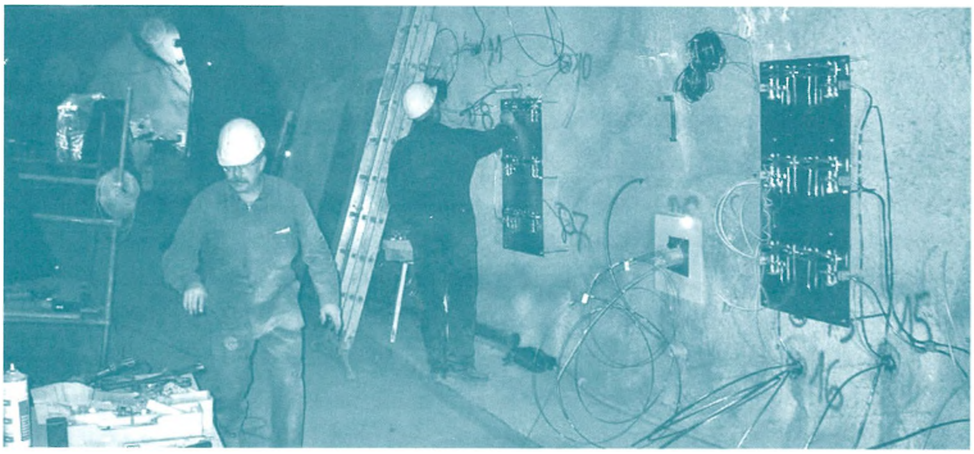
→ made of appropriate materials to prevent significant reactivity between waste/container/complementary overpack (canister)/natural environment within the environmental conditions foreseen. Moreover, the probability of galvanic corrosion has to be kept to a very low level. Such complete isolation of the waste may be used in order to benefit from radioactive decay and to prevent infiltration water to reach the waste while its temperature is too high. In addition, the physical and chemical properties of the packages should act, once the isolation envelope has failed, as a retardant to the release of radionuclides under the environmental conditions expected to be encountered in the disposal facility. Low reactivity between the conditioned waste and the minerals found in its environment should be sought;

- the amount of reactive and complexing substances in the packages should be as little as possible to prevent a possible increase of the radionuclide solubility and a decrease of the host-rock retention capacity;
- the thermal characteristics of the waste should not alter the favourable properties of the packages, of the engineered barrier and of the geological layer;
- the mechanical properties of the packages should enable their withstanding waste stacking, engineered-barrier swelling and host rock converging, at least for the period of time where waste isolation is necessary. Moreover, the presence of voids should be limited as far as practicable.

Lastly, the knowledge gained on the material possibly used for manufacturing the packages should have reached a level compatible with convincing long-term performance assessment.

> Waste package design: a key to the flexibility of disposal facilities

As a matter of fact, the packages formerly or presently produced do not necessarily possess all the aforementioned properties. This does not mean they are not acceptable in future storage or disposal facilities, as measures to balance their possible weaknesses can be implemented with a view to demonstrating that a high level of safety can nevertheless be reached in the facilities. However, the design of future waste packages should benefit from these considerations so as to efficiently contribute to the safety of the storage and disposal facilities due to receive them, allowing them to be designed with more flexibility. ■



Installation of pore water pressure transducers

REVERSIBILITY AND RETRIEVABILITY: A CONTRIBUTION TO SAFE DISPOSAL?

By Hans Riotte,
Head, Radiation Protection and Waste Management Division, OECD/Nuclear Energy Agency (NEA)

There is a consensus among the technical community that final disposal in engineered geologic repositories provides a safe and ethical method for the long-term management of long-lived radioactive waste. In this respect, it must always be kept in mind that the ultimate goal of a repository is to provide passive, safe isolation of waste over the long term, and that retrievability is only a sub-goal or preference. However, several stakeholders also demand future controllability and retrievability of waste placed in underground repositories. Many disposal organisations have therefore chosen to consider the possibilities for incorporating the concepts of reversibility and retrievability in their programmes.

Reversibility and retrievability: definitions

Reversibility and *retrievability* have been considered in some national programmes from the earliest times from technical, policy, and ethical perspectives. The two terms are used to distinguish between *procedural* and *technical* aspects of a design which introduces flexibility in the implementation of a geologic repository:

- Reversibility denotes the possibility of reversing one or a series of steps in repository planning or development at any stage of the programme. This implies the review and, if necessary, reassessment of earlier decisions, as well as the necessary means (technical, financial, etc.) to reverse a step.
- Retrievability refers to the possibility of reversing the action of waste emplacement and to technically recover the waste or waste packages. Retrievability may be facilitated by the repository design and operational strategies, e.g. by leaving underground access ways open until a late stage, and through the use of durable containers and easily excavated backfill.

> Flexibility and responsibility towards future generations: a delicate balance

The planning and implementation of a geologic repository is typically guided by an incremental, stepwise approach. At each step, the decision to proceed or not is made in the light of technical factors and, also, social and political acceptance [1]. ➔

[1] On this topic, see "*Implementation of Repositories: the Benefits of a Stepwise Approach*", by Bruno Baltes, GRS.

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"Retrievability and reversibility should not be seen as a lack of confidence in ultimate safety of disposal, but rather as a desire to make optimum use of the available waste management options and design alternatives."

➔ By introducing a specific flexibility to such a stepwise approach, retrievability and reversibility can contribute to making stakeholders confident that an irreversible decision is not being made. In any event, complete flexibility cannot be retained throughout the development process, since progressively firmer decisions must be made in proceeding from one development stage to the next, if the final goal of providing long-term passive safety is to be met.

While reversibility is consistent with the ethical principle that the needs and aspirations of future generations should be respected, including their freedom to make their own decisions, a balance has to be struck between this and the complementary principle that undue burdens should not be placed on future generations. These burdens may include requirements to monitor the repository, to maintain the appropriate technical expertise, and to maintain administrative and decision-making capabilities.

> Practical arrangement in a hazy regulatory framework

In some countries with a policy or preference for geologic disposal, it is considered that closure of the repository should not be delayed unnecessarily. In a few other countries such as the United States, the possibility of retrieval is mentioned in legislation or regulation. In general, however, guidelines are not given on how any requirement for retrievability should be implemented. Many waste management organisations are focusing their efforts on developing a final repository from which the waste is retrievable, at least for some period of time after emplacement. This is the case *inter alia* in Finland, France, Sweden, Switzerland, the United Kingdom and the United States, where modifications of the geological disposal concept have been adopted or are considered that deliberately extend the period during which a repository might be held open, beyond completion of waste emplacement. In such cases, a longer period of time is envisaged during which the waste would be monitored and, if needed, could be retrieved by reversal of the emplacement process.

> Preserve adequate safety and security in the long term

Any provisions for retrievability must be implemented in a manner that preserves adequate safety and security during both the operation of the repository and in the long term. A significant milestone in the development of a repository from technical, administrative, and social perspectives, final closure should be performed when:

- no circumstances have been identified that would require urgent retrieval of waste;
- adequate confirmatory data have been collected to provide reasonable assurance that the facility will perform as intended;
- public confidence is sufficient to warrant the associated discontinuation of the underground monitoring and increase in the difficulty of retrieval.

Even if retrieval became the preferred option at some future time, there would always be time to implement it in a judicious manner, i.e., when an alternative storage or disposal facility was prepared to receive the retrieved waste. This allays the need for stand-by, redundant systems for waste storage or alternative disposal routes. ■

Waste retrieval: the pros and cons

Broad factors that might lead or contribute to a decision to retrieve waste, and weigh in favour of building provisions for retrievability, are recognised to be as follows:

- a desire to recover resources from the repository, e.g. components of the waste itself – in particular fissile material – or the recognition or development of some new resource or amenity value at the site;
- a desire to use alternative waste treatment or disposal techniques that may be developed in the future;
- technical safety concerns that may only be recognised after waste emplacement and/or changes in acceptable safety standards;
- response to changes in social acceptance and perception of risk, or changed policy requirements.

There may, however, be technical, policy-related, and security disadvantages which deserve consideration. Reasons for not including retrievability provisions in repository design may be connected to factors such as:

- the favouring of irresponsible attempts to retrieve or interfere with the waste during times of political and/or social turmoil when safeguards and monitoring features are no longer in place;
- the possibility of failure to seal a repository properly due to the adoption of extended or more complex operational plans to favour retrievability;
- uncertainty about negative effects, including conventional safety and radiological exposure of workers engaged in extended operations and/or associated monitoring, or marginal gains;
- a possible need for enhanced nuclear safeguards.

“Closure of repository marks the transition from an underground facility from which retrieval may still be contemplated to a final disposal facility.”

Performance of test drillings

FROM UNDERGROUND RESEARCH LABS TO WASTE REPOSITORY: SCIENTIFIC, ENGINEERING AND LICENSING APPROACH

By Juhani Vira,
Vice President, Research Posiva Oy, Finland

The idea of the final suitability confirmation with an underground rock characterisation facility has been included in the Finnish safety regulations for final disposal of spent fuel. Such need was also recognised very early in Posiva's programme for the implementation of a spent-fuel repository, but its precise position in this process was fixed only later in the 1990's, as the regulatory requirements were defined. In this definition, the underground characterisation marks a smooth transition from the surface studies to the actual implementation of disposal.

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Underground rock laboratories are a necessary step to establish the validity of investigation results

A NEA report published a few fears ago found a total of 26 different examples of underground rock laboratories (URLs) built for nuclear waste research and investigations in NEA member countries [1]. These split into two categories:

- *generic URLs*, built in existing rock excavations or designed especially for nuclear waste research purposes;
- *site-specific URLs*, located at sites eventually destined to become repository sites.

Among the high-level waste site candidates, there is some level of political decision to go ahead with repository development only at the Yucca Mountain (USA) and ONKALO (Finland) facilities. However, regardless of the type of facility, all of the URLs are, in one way or another, parts of the stepwise development towards a safe final solution for nuclear wastes.

It seems that a fair description of the rock conditions at the repository site can be built on the basis of borehole studies and other surface investigations, and that many of the repository technologies can be tested without building any underground facilities for that purpose. Nevertheless, it may be difficult to establish in a convincing way the validity of the results from those investigations and demonstrations without ever really going underground. In that sense, URLs may be a necessity for any successful geologic repository programme.

[1] *The role of underground laboratories in nuclear waste disposal programmes.* Nuclear Energy Agency (OECD), Paris 2001.

> Onkalo: a smooth transition from laboratory investigation to repository operation

Finnish safety regulations call for suitability checks through underground investigations of the host rock as a prerequisite to application for a construction license. The Finnish waste management company Posiva – which cooperates with the Swedish nuclear fuel and waste management company SKB at the Äspö URL in Sweden – is therefore involved in the construction of the Olkiluoto rock characterisation facility Onkalo, currently underway in Finland. The Olkiluoto site was selected to harbour the repository for the spent fuel produced by the Finnish NPPs, and the Onkalo facility should provide the final proof of suitability of the Olkiluoto bedrock for radioactive waste disposal purposes. Although Posiva believes that the 15 years of site investigations at Olkiluoto have already given a good basis for the suitability assessment and expect no major surprises from the Onkalo, this laboratory phase is nevertheless considered important for learning the practices needed for the implementation of the disposal plans. The main purpose is to provide a smooth transition from investigation and construction work to the actual repository operations.

> The challenge resulting from contradictory requirements

The more intrusive work is performed, the better the site knowledge may become. But at the same time, the site may lose some of the features that could make it a good repository site, as the disturbance caused by the excavations and other possible testing activities may finally complicate the safety case and add to the uncertainties of the safety assessment. This contradiction is a real challenge for underground working at a real repository site. Therefore:

- a proper balance has to be struck between the investigation and demonstration interests and those aimed at safeguarding the good host rock properties;
- it may be easier to do the more generic testing and demonstration work at generic URLs and save the rock characterisation facilities at repository sites for those activities that really have to be carried out *in situ*.

Posiva thinks much of the demonstration activities can well be performed at Äspö, but is aware that some of the conditions – salinity, for instance – are different, and that the impact of those differences must perhaps be tested at the actual Olkiluoto repository site.

> Onkalo: still a research facility, yet a repository from a regulatory perspective

Posiva has established a specific quality assurance (QA) system for all activities at the Onkalo site. The system is based on IAEA's safety guides and the regulatory guides prepared by STUK, the Finnish Radiation and Nuclear Safety Authority, taking into account the ongoing revision process of the guidelines. The guidance calls for a graded approach, in which the level of the quality assurance measures taken for any particular activity is set to correspond to its significance for safety. According to the long-term safety relevance of various activities, three categories were established:

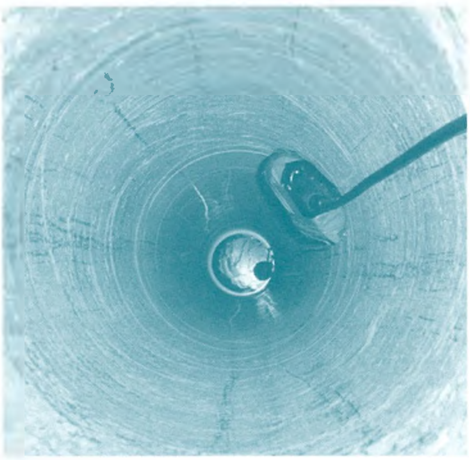
- Class A activities, which are known to have relevance for the →

→ long-term safety properties of the site;
- Class B activities, which have potential or indirect relevance for long-term safety;
- Class C, which includes the rest of activities.

For the safety-critical activities, special requirements and instructions have been set up; for the less critical activities (Class C) the normal QA based on ISO requirements is considered sufficient.

Still a research and investigations facility, ONKALO is not subject to regulatory control yet. However, Posiva is planning to use it as an access to the repository and, hence, as a part of the repository. It has therefore agreed with STUK that the design and construction of the ONKALO facility as well as the investigations carried out there are already subject to a specific programme of follow-up, inspection and supervision aimed at ensuring that STUK receives the necessary information for the eventual licensing process and that Posiva receives the necessary feedback in due time.

This programme also includes the development of the safeguards policies and techniques compliant with the international non-proliferation agreements. At the moment the detailed requirements for safeguards control at geologic repositories are still in preparation internationally. Posiva is ready to co-operate in the establishment of practicable working procedures for such control.



View into a test borehole

> Different countries, different approaches but a shared need for demonstration

Posiva's programme for the implementation of a spent-fuel repository is an example of a stepwise process defined in its main steps more than twenty years ago. In this process, the precise position of an underground rock characterisation stage was fixed later in the 1990's, as the regulatory requirements were defined. In this respect, the underground characterisation marks a smooth transition from the surface studies to the actual implementation of disposal and is planned before the application for a construction license is submitted.

The fact that the characterisation facility is meant to become an auxiliary part of the actual repository adds some complexity to the regulatory arrangements. But the progress so far indicates that a working regulatory framework can be established as soon as all parties understand their roles in the overall licensing context. In other countries, different policies may be adopted as regards the role and timing of the underground characterisation. In any case yet, there is a need at some point of the process for consensus between the regulator and implementer on the kind of rock that is considered suitable for different parts of the repository and on the methods to verify the suitability. ■

IMPLEMENTATION OF REPOSITORIES: THE BENEFITS OF A STEPWISE APPROACH

By Bruno Baltes,
Head of the Final Storage Department, GRS, Germany

As nuclear waste disposal in geological repositories can only be achieved in consensus with society, a project approach allowing participation and co-determination by the different stakeholders is increasingly regarded as appropriate. It is therefore implemented at varying degrees in several national repository programmes. Moreover, such a stepwise approach to the implementation of a repository system is discussed in many national and international institutions. Its advantages and requirements are presented below.

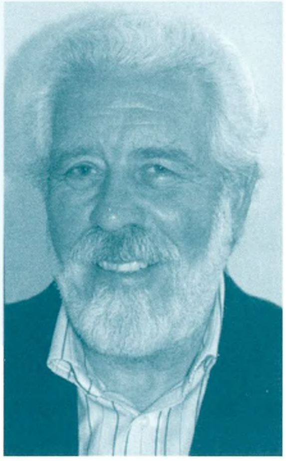
The first and ultimate objective of nuclear waste disposal is to ensure the protection of man and the environment against the detrimental effects of nuclear waste. It is therefore carried out according to the concept of concentration and isolation in suitable deep geological formations in such a manner that the safety requirements can be met for long geological periods.

> Social acceptance, a pivotal part of decision making

The development of modern industrial societies has led to a changing understanding of safety and a need for security as well as to the demand for participation and co-determination by the public. Thus, project decisions only based on technical advances are usually not sufficient to ensure smooth implementation. Particularly projects of major social relevance will not meet the acceptance required for their progress unless all significant social powers are involved in the decision making. This also applies to the implementation of nuclear waste repositories which lasts over a period of many generations and requires public confidence in the system's long-term passive safety once it has been released in the post-operational phase.

> Stepwise approach, the basis for an open and transparent process

This social development made the involvement of all relevant social groups – politicians, institutional players and the public – in the implementation process of a repository system a prerequisite. The process must allow for the co-operation of all players in a practicable manner, facilitating a purposeful dialogue with consideration of all decisions. This calls for a stepwise approach with defined breakpoints where decisions on the further development of the process are made. The various steps are →



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→ defined based on the respective project phases which specify required decisions to be made with participation of all stakeholders, drawing upon the state of the art in science and technology, new technologies, current findings on the project, potential options as well as political, social and economical aspects. In addition to the institutional players, the public is involved in the decision-making process. Thereby, decisions made at previous process steps can be reappraised according to new findings.

At each step, the safety aspects of nuclear waste treatment and final disposal direct the process. An open and transparent process enables all players to assess the facts as, for example, whether the safety objectives can be achieved by the intended measures or whether alternative options need to be considered. For the preparation of a sustainable decision, the process requires sufficient time for the purpose of complete stakeholder information and, subsequently, of a competent and fair debate.

> Enhancing the quality and legitimacy of decisions

Considering the project progression and control, a stepwise approach enables the technical and social developments going along with any long-term process to be taken into account more easily. It also enhances the quality as well as the legitimacy of decisions, as the overall social responsibility for solving the problem of nuclear waste disposal in geological repositories is enforced. Last but not least, an iterative stepwise process opens up the opportunity to reconsider decisions up to the reversibility of the whole procedure.

According to the principle that safety has absolute priority in all decisions, the stepwise approach offers the opportunity to find consensual answers to recurring fundamental questions, such as:

- What does safety in terms of final disposal mean – e.g. safety of man and the environment, reasonable burden on future generations, etc. – in particular during the post-operational phase?
- How can safety be checked during the post-operational phase?
- What is the current knowledge of the state of the art in science and technology?
- When is the knowledge sufficient to implement a repository system?

A stepwise approach offers the chance to find a justifiable and consensual solution to the overall social issue of radioactive waste disposal.

> The necessity of a regulatory framework

A legal framework is required to conduct the implementation process of repository systems efficiently and practically. It needs to determine:

- a stepwise process,
- the parties involved – politicians, operators, institutions, other stake-holders,
- their respective competences.

To assist in reaching decisions and to facilitate the process development, a regulatory framework dealing with the integration of stakeholders in the process is required. It should specify:

- on one hand, which groupings represent the public in the process and,
- on the other hand, which tasks, rights and duties are assigned to the players for the purpose of a successfully conducted process.

A three-fold process

The implementation of a repository system is composed of three major phases:

- the pre-operational phase including site selection;
- planning, design and erection;
- the operational phase and the decommissioning phase including repository closure.

Spread over many decades, this process is followed by the temporally limitless post-operational phase. Some countries plan a period of active monitoring before releasing the repository system into the post-operational phase.

The implementation is to be seen as a process in which diverse social as well as technical and scientific sub-processes co-operate:

- political decision-making for final storage;
- technical development of the repository system by the institutional players such as the applicant and the licensing authority;
- public involvement.

From a technical and scientific perspective, the progress of the implementation process of a repository system requires a stepwise approach with stepwise decisions pertaining to:

- the development of a repository concept including safety functions of the barrier system for the required isolation period;
- the selection of a site where the repository concept is to be implemented;
- the site characterisation and suitability assessment;
- the provision of sufficiently reliable data and knowledge for the implementation of a repository;
- the design of the repository drawing upon the site characterisation;
- site-specific safety cases for the operational and post-operational phases;
- the evaluation and approval by the authorities;
- the repository erection and operation.

Per se, the process described above is a stepwise approach based on technical and scientific developments. However, it should also be implemented as an iterative process including, for each process step:

- the definition of a set of criteria for the evaluation of the findings prior to step inception;
- the submission of a comprehensive document set about the repository system's safety based on the respective state of knowledge (safety case). ■

> "A stepwise approach with defined break-points where decisions on the further development of the process are made facilitates a purposeful dialogue among all of the players in a repository project."

MANAGEMENT OF NUCLEAR WASTE IN TRANSITION COUNTRIES: CHALLENGES AND PROGRESS

By Lumir Nachmilner,
Waste Management Consultant, Czech Republic,
currently with Waste Technology Section, IAEA

By allowing an exchange of information previously restricted to the IAEA channel, the collapse of political barriers between the Western and Eastern parts of Europe was a real breaking point in the field of radioactive waste management. It appeared that 'old' democracies were not used to place confidence in the waste management practices beyond the Iron Curtain, in so called "transition countries". Nevertheless, even if a vast majority of transition countries are still coping with the burden inherited from past, they succeeded, backed by EU assistance, in improving significantly their waste management systems during the last decade.

Lumir Nachmilner
Waste Management Consultant, currently with Waste Technology Section, IAEA

An insight into some typical problems such countries have been faced with and directions they have selected for the safe management of radioactive waste is proposed below.

> Dealing with a burdensome heritage

Most of the transition countries are still suffering from limitations inherited from history and the intrinsically small size of their nuclear programmes:

- Past practices resulted in a fragmentary legal and administrative infrastructure, a lack of financial means, insufficient expert capacity and capability, outdated disposal facilities, historical radioactive burdens, and… a totally disregarded public opinion.
- If small-size nuclear programmes may generate adequate financial means to cover the direct cost of waste management, they are hardly sufficient for financing support activities. This means that transition countries can be barely involved in international teams working on basic theoretical and practical aspects of waste management technologies. In this field their role is mostly limited to sharing existing underground research laboratories or participating in particular EC projects. The only exception is probably the coordination of the EC *Support Action: Pilot Initiative for European Regional Repositories* (Sapierr) project by the Slovak institution Decom.
- Since nuclear waste management is a costly and non-profitable activity, investments were kept at minimum level, ad-

versely affecting the availability of such specialised capabilities as waste management experts, managers and regulators. Only small teams (staffed with some tens of people) were thus created to plan and carry out required activities with some backing by external contractors. Moreover, regular independent technical support from regulatory bodies did not practically exist. Therefore, training and involvement of their experts in multinational projects, and the creation of a competitive environment in managing radioactive waste belong to the main challenges for transition countries.

- For building repositories, a tendency was in favour of using existing underground spaces, typically abandoned mines, without adequate engineered constructions. There has been a clear need for a reassessment of the suitability of these old disposal systems and for their upgrading.
- In addition, the former regimes in transition countries were rather restrictive and did not allow any open discussion about such sensitive issues as the siting of nuclear facilities. Suddenly released, the previously bypassed public opinion opposed systematically every industrial project, making any attempt of transferring negotiation procedures applied in 'old' democratic countries quite inoperative.

> Progress achieved

Faced with the challenges mentioned above, the transition countries succeeded in reaching significant improvements of their waste management systems in the past decade:

- Most countries adapted their legislative documents and infrastructure to the standard existing in EU countries.
- Five of them initiated the development of near-surface repositories to satisfy their needs for operational and decommissioning waste disposal capacities.
- Together with redefining the role of supervisory bodies, the national waste management systems were completed by creating nuclear accounts collecting funds to cover the costs of making waste harmless.
- For assuring state guarantee for long-term management of radioactive waste, specialised agencies were created and entrusted with the disposal of radioactive waste, research in the field and the development of relevant facilities.
- Waste inventories as well as the safety of old disposal facilities were revised in several countries, often with the assistance of the IAEA or within the framework of EC PHARE projects.
- Repository upgrading also allowed for the waste resulting from the decommissioning and dismantling of old radiochemical facilities, including research reactors.
- Some countries have formulated national waste management strategies indicating their plans in medium- and long-term time horizons (Hungary, Czech Republic).
- When considering relatively small nuclear programmes, the transition countries were encouraged at international level to consider a multinational facility for disposing of high-level waste. As the issues to be solved to allow such projects are far more political than technical – therefore requiring negotiations at governmental level – they are however unlikely to be tackled in the near future. →

Some useful links

ANDRAD, Romania
www.andrad.ro

APO, Croatia
www.apo.hr

ARAO, Slovenia
www.arao.si

DP RAO, Bulgaria
www.dprao.bg

PURAM, Hungary
www.rhk.hu

RAWRA, Czech Republic
www.rawra.cz

RATA, Lithuania
www.rata.lt

RAPA, Latvia
www.rapa.lv

ZUOP, Poland
www.zuop.pl/ksop.html

VYZ, Slovakia
www.seas.sk/power-plants/nuclear-installations

Joint convention on the safety of spent fuel and radioactive waste management
www-ns.iaea.org/conventions/rw-national-reports.htm

• The democratisation processes made the public a fully-fledged stake-holder in the management of the back-end activities. Thus, not only municipalities, but also opponent groups – either coalesced spontaneously or organised internationally – must be taken into account when planning waste disposal facilities. Backed by juridical services and using mostly irrational arguments to influence public opinion, they pose a new set of problems to be solved. It is gratifying to note that some positive results have been achieved in Hungary and recently in Slovenia.

Last but not least, the increased effectiveness of international assistance is another positive feature. It shifted from mapping the waste management status quo and problems to building national capacities and capabilities. This plays a pivotal part in developing updated and internationally accepted waste management systems. And the final target could be clearly specified as turning assistance activities into the joint development of advanced solutions, technologies and facilities. ■

Transition countries: common challenges, distinctive options

Bulgaria: in search for solutions

- State Enterprise Radioactive Waste established in 2004
- Near-surface repository at Novy Han (upgraded with the help of EC) to accept mostly institutional waste
- New near-surface repository to be opened for waste generated by NPP operation and decommissioning

Czech Republic: wondering how to continue

- Waste management agency RAWRA established in 1997
- National waste management strategy approved in 2002
- 3 operational near-surface facilities provide enough capacity for accepting LLW to be generated until end of century
- Programme of geological repository development initiated in 1993 criticised from both technical and political spheres without offering other concrete and complete solutions

Hungary: systematically going ahead

- National waste management agency PURAM established in 1997
- Facility for LLW + ILW to be commissioned in 2008, geological repository in 2047
- Püspökszilágy facility being upgraded to create new capacity for institutional waste

Lithuania: solving historical problems

- Single NPP (Ignalina) to be phased out and decommissioned
- National waste management agency RATA established in 2001
- Siting of repository for both operational and decommissioning LLW + ILW in progress

Latvia and Poland: waiting for the future

- No NPP in operation
- Latvian (RAPA) and Polish (ZUOP) waste management agencies established in 2000 and 1999, respectively
- Faced with the decommissioning of research reactors and disposal of waste in old repositories
- Both Rózan (Poland) and Baldone (Latvia) facilities due to safety accept institutional waste

Romania: groping

- Nuclear energy programme and nuclear research maintained
- Waste agency ANDRAD established in 2003
- Further usability of existing repository Baita Bihor not established
- Capacities for waste conditioning missing both in institutional and power sectors
- Started preparation of the national waste management strategy

Slovakia: waiting for completion of structural changes

- VYZ responsible for the decommissioning of old A1 reactor and for waste treatment from all government-operated facilities
- Surface repository operated by VYZ
- Geological repository programme initiated in the mid-90s
- Site investigations focused on 3 regions presently frozen

Slovenia and Croatia: starting in the right direction

- NPP operation and management of spent fuel as well as radioactive waste shared
- Institutional waste managed separately
- Slovenian (ARAO) and Croatian (APO) waste management agencies both established in 1991
- Generic studies of both near-surface and geological repositories completed, providing information about potential timing and duration of NPP decommissioning, and about needs for disposal capacities

EVENTS & WEBSITES

Upcoming meetings on radioactive waste management

➤ *17-20 September 2006, Olkiluoto (Finland)*
TopSeal 2006, International Topical Meeting on Waste Management
Organised by ENS

➤ *25-29 September 2006, Nîmes (France)*
9th Information Exchange Meeting on Actinide and Fission Product Partitioning & Transmutation
Organised by OECD/NEA

➤ *11-15 December 2006, Athens (Greece)*
International Conference on Lessons Learned from Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities
Organised by IAEA

A few website links for reading more about decommissioning

➤ **Disposal of Radioactive Waste: Forming a New Approach in Germany**
FSC Workshop Proceedings, Hitzacker and Hamburg, Germany, 5-8 October 2004
http://www.oecdbookshop.org

➤ **French R&D on the Partitioning and Transmutation of Long-lived Radionuclides**
An International Peer Review of the 2005 CEA Report
http://www.nea.fr/html/ndd/reports/2006/nea6210-french-research.pdf

The next EUROSAFE Forum will be held in Paris on 13 and 14 November 2006 focusing on Radioactive Waste Management

The ninth issue of the EUROSAFE Tribune will contain reports about the lectures and discussions of the 2005 Brussels Forum

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