International Workshop on

High-level Radioactive Waste and Spent Fuel Management:

Storage and Disposal

Näringslivets Hus, Stockholm, Stockholm, Sweden

29 November 2011 – 1 December 2011

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Workshop scientific secretary: David Bennett, TerraSalus ltd

Tuesday 29 November 2011

1. Welcome and Introductions

Johan Anderberg opened the meeting by welcoming the participants on behalf of the Swedish Radiation Safety Authority (SSM). Thanks were given to the International Atomic Energy Authority (IAEA) in organizing the workshop and to the Swedish Nuclear Fuel and Waste Management Co. (SKB) for their cooperation iin in particular for arranging the technical visits. Johan Anderberg explained that the workshop was intended to examine many aspects of high-level waste (HLW) and spent fuel management and disposal, but with a focus on sustainability and intergenerational equity.

Magnus Vesterlind welcomed the participants on behalf of the IAEA. He stressed the fact that IAEA Safety Standards require safe management of HLW and spent including their geological disposal but, that in some countries there seems to be a trend towards developing strategies of longer waste storage periods instead of developing and consequently implementing disposal programmes. Experience shows that it takes decades to research, site, design, construct and operate and licence HLW and spent fuel disposal facilities and this suggests that work on disposal should begin at the start of a nuclear power programme.

The workshop was chaired by Walter Blommaert of the Belgian Federal Agency for Nuclear Control (FANC), who recalled the structure of the workshop with a series of invited presentations and working group sessions at which participants would have a chance to discuss and address key issues on HLW and spent fuel storage and disposal. The working groups sessions would occur on the first two days of the workshop and the working groups would report back to the full meeting on the morning of the third day, prior to a panel discussion. The workshop was attended by 62 participants from 29 countries and

International organizations (Appendix 1). David Bennett of TerraSalus Ltd acted as Scientific Secretary for the workshop and prepared this synthesis of the workshop discussions.

2. Keynote Presentations

The workshop received three keynote presentations:

1. Hans Riotte of the OECD Nuclear Energy Agency (NEA) gave an international overview of the status of spent fuel storage and disposal.
2. Ute Blohm-Hieber of the European Commission (EC) presented the recently adopted European Directive on Responsible and Safe Management of Spent Fuel and Radioactive Waste.
3. Olle Olsson of the Swedish Nuclear Fuel and Waste Management Co. (SKB) gave an overview of SKB's spent fuel disposal project license application.

The slides from these presentations are included in Appendix 2. The following paragraphs highlight key points and summarise the associated workshop discussions.

2.1. International Overview of the Status of Spent Fuel Storage and Disposal

During his presentation, Hans Riotte noted that conventionally, spent fuel storage has been seen as an interim management step, lasting for at most a few tens of years. Wastes may be stored for several reasons including allowing time for radioactive decay and cooling, and for logistical reasons e.g. 'buffer storage', 'interim storage'. |However, indefinite storage is not sustainable and would place undue burdens on future generations. As well, the development and use of advanced fuel cycles, such as those envisaged involving gas-cooled fast reactors with internal transmutation, would not remove the need for final disposal. Hans Riotte also explained that worldwide there is currently substantial spent fuel storage capacity available, but that projections suggest that by ~2030 this available capacity will be diminishing, especially in the US. Current spent fuel stores are typically designed with lifetimes of 60 to 100 years, which should give enough time to develop and licence disposal facilities. Extending storage periods beyond 100 years may bring several technical and non-technical challenges, including:

- The need for better waste packages.
- The possible need for specific fuel designs.
- Fuel, container and concrete degradation.
- Decreasing fuel cladding ductility.
- Hydride precipitation.
- On-going needs for maintenance, record keeping and funding.
- Societal and economic instability.
- Public acceptance.

Regarding reversibility and retrievability, Hans Riotte noted that disposal will be implemented in a gradual way that will provide for reversibility of waste disposal actions and for waste retrievability. The ease of retrievability will de facto decrease with time.

Discussion

Safety of extended storage periods. Regarding the safety of storing spent fuel for more than 100 years, there is less confidence in the ability to store spent fuel safely for more than 100 years, as this has not been attempted and raises several challenges (see above). In general, it is more difficult to ensure the safety of spent fuel storage using storage pools than dry stores, and it is expected that there will be a transition from wet to dry storage. Existing stores are re-licensed every ten years or so, and this process includes review and assessment of their safety.

Acceptability of extended storage periods. During the discussion on the public acceptability of extending waste storage periods, it was noted that communities would often not accept interim waste stores unless there was seen to be planning for, and steps towards, the implementation of waste disposal. Waste management organisations and governments should be open and transparent regarding intentions for the period of waste storage and plans for waste disposal.

Storage Capacity. Projections on storage capacities indicate that by ~2030, spent fuel storage capacity may be running out and that by that time most countries will not have operating disposal facilities. The projections are based on broad assumptions but they do suggest a need to make more progress in implementing waste disposal. It was noted during the discussion that it may be no easier to site, construct and licence centralised storage facilities than geological disposal facilities, particularly if new storage arrangements require increased waste transportation, which is often a focus of public objections.

Centralised storage Although centralised waste storage does lead to increased waste transportation, it does add flexibility to the overall waste management system because it does away with the need to maintain stores at each nuclear power plant (NPP) and allows the power plants to be decommissioned. It was also noted that the risks associated with waste transport are very low, although this does not necessarily make it easy to gain public acceptance for waste transport.

Costs and funding. The idea that a period of waste storage would allow time for disposal funds to grow was questioned. It was also noted that waste storage itself requires up-front investment and on-going funding. Previously it has been assumed that waste management funds will grow appreciably with time, but current forecasts of growth rates are less optimistic.

Political and societal stability. It was pointed out that in some countries there is a relatively high risk of instability, including changes to governments and wars. It was suggested that

this is a driver to implement a disposal solution more quickly, but not on the detriment to safety, and not to store wastes on the surface.

Borehole disposal. Questions were asked about the possibility of borehole disposal for HLW and spent fuel. It was suggested that the use of deep boreholes would enable the waste to be rapidly isolated from the accessible environment. It was noted that the safety and feasibility of deep borehole disposal is at a very early stage of research. It has still to be demonstrated and currently the true difficulties associated with implementing the borehole approach might be being underestimated. It was also explained that there is a trade-off between increased isolation and retrievability. Retrievability is often viewed by the public as being very important and although deep boreholes might provide isolation, waste retrieval would be more difficult.

2.2. European Directive on Responsible and Safe Management of Spent Fuel and Radioactive Waste

Ute Blohm-Hieber of the European Commission (EC) gave a summary of the European Directive on the Responsible and Safe Management of Spent Fuel and Radioactive Waste in the EC (Council Directive 2011/70/Euratom), which was adopted on 19 July 2011**.** The Directive requires:

- A community framework ensuring responsible and safe management of spent fuel and radioactive waste to avoid imposing undue burden on future generations.
- National arrangements for a high-level of safety to protect workers and the general public against dangers arising from ionising radiation.
- Public information and participation.

According to the Directive, spent fuel may be regarded either as a valuable resource that may be reprocessed, or as radioactive waste that is destined for direct disposal. Whichever option is chosen, the disposal of high-level waste, separated at reprocessing, or of spent fuel regarded as waste should be addressed. The type of disposal should be commensurable with hazard posed by the waste.

According to the Directive, waste storage, including long-term storage, is an interim solution, not an alternative to disposal. In the longer term, only disposal with its inherent passive safety can provide sufficient protection against the potential hazards.

In general, spent fuel and radioactive waste must be disposed of in the member state in which it is generated. The Directive would allow disposal facilities to be shared between states in the European Union. Waste disposal outside of the EU would only be allowed under very strict conditions – including that the level of safety in the destination country would have to be at least as high as within the EU.

The Directive requires all of the components that would be expected in a safety case for disposal, although it does not explicitly use the term safety case.

The Directive requires member states to establish, and provide information to the EC on its national programme for spent fuel and radioactive waste management, and to ensure that international peer reviews of the national programme, including their implementation, are conducted at least every 10 years. The Directive goes beyond assessing safety; it requires member states to make tangible progress on the implementation of geological disposal.

Discussion

Definition of disposal. On a question on whether the Directive defines disposal as occurring at the time a disposal facility is closed, it was explained that the Directive is not specific on this point – rather, the Directive leaves each member state to define its own approach to disposal. However, the Directive does indicate that geological disposal is the preferred approach for HLW and spent fuel, and it requires the post-closure safety of disposal facilities to be assessed.

Duration of interim storage. Regarding the Directive specifies how long a period of interim storage is acceptable. Ute Blohm –Hieber also explained that the Directive does not specify how long a period of interim storage is acceptable, but that the period of storage chosen by the member state will have to be notified to the EC and will, thus, be in the public domain and open to stakeholder consideration.

Peer reviews. The Directive requires member states to ensure that international peer reviews of the national programme for spent fuel and radioactive waste management are conducted at least every 10 years. It was asked whether the peer reviews would just check that the national programme includes milestones towards disposal, or whether the peer review would also be able to challenge the schedule of milestones. It was explained that the peer reviews would be able to question the schedule, particularly if it was considered not to be credible. Regarding the EC plans to evaluate the implementation of the results and recommendations of the peer reviews, at this stage the EC's plans on this are still under development, but the EC will expect the national programmes demonstrably to take account of peer review recommendations. Following questions on the standardisation of peer review procedures, It was mentioned that the IAEA has initiated the development of guidance on such procedures and this is being encouraged by the EC.

Shared disposal facilities. Questions were asked regarding how an international shared disposal facility might be licensed and regulated. This has not been defined and although the EC would encourage collaboration between member states, it will not direct states to do this. Some participants felt that in accordance with the regulation of other industrial sectors, licensing of a shared waste disposal facility would have to be done by the regulatory authority from the country in whose territory the facility was located.

2.3. SKB's Spent Fuel Disposal Project License Application

Olle Olsson of SKB gave an overview of SKB's spent fuel disposal project license application. The programme for spent fuel disposal in Sweden began in 1976. Around 35 years of consistent, systematic work have been conducted to engage local populations in dialogue on geological disposal, select a site and develop a licence application, which was submitted to the regulators in March 2011. SKB's licence application comprises ~10,000 pages and cites ~4,000 references, themselves totalling over 100,000 pages. In the licence application, SKB is applying for permission to continue interim storage of wastes at the existing centralised storage facility CLAB, to construct and operate a new spent fuel store called Clink which will incorporate a spent fuel encapsulation plant, and to construct a geological repository at a depth of ~470 to 490 m in granitic rocks at Forsmark. The licence application includes a single Environmental Impact Assessment that spans all the facilities for which permission is being requested. SKB is separately planning to extend the existing shallow sub-surface low-level waste disposal facility at Forsmark to accept decommissioning wastes.

The licence application includes an analysis, known as SR-Site, of the "long-term safety of a final repository for spent nuclear fuel" constructed according to the KBS-3 disposal concept, in which spent fuel is placed in copper canisters that are disposed of inside a bentonite clay barrier, or buffer. SR-Site has two aims; an assessment of safety and the provision of feedback to facility design and the forward plan for research, development and demonstration (RD&D) work. SR-Site indicates that the risks associated with geological disposal of spent fuel at Forsmark are below the regulatory criterion of 1 in a million per year, even though there are some circumstances (corrosion following buffer erosion, earthquakes) in which a few waste containers might fail.

SKB has a plan for a series of further disposal facility assessments and licence reviews over the next 15 years leading through construction, test operation and then full operation.

Discussion

The need for further RD&D. On this point, even if SKB is already confident enough on the project to submit the licence application, the RD&D work is needed to move towards full industrialization of disposal, to further strengthen the scientific basis for the safety case by reducing uncertainties and conservatisms, and to keep and develop public confidence.

Test Operation of the Disposal Facility. Regarding the aims and duration of the test operation period for the final disposal facility, SKB envisages that the phase of test operations would last just a couple of years. The aim would be to test the operating procedures, not verify the long-term safety of the facility.

Waste retrievability. On the Questions on whether it will be possible to retrieve spent fuel disposed of in the Swedish geological disposal facility according to the KBS-3 method, SKB

indicated that although waste retrieval is technically possible, it should not be necessary and it is not the intention to retrieve the wastes.

Regulatory interactions. Regarding Swedish arrangement for regulatory interactions between SSM and SKB, the Swedish Law mandates regulatory review of the tri-annual RD&D plan, and in addition the Swedish Government decided that there should also be close consultations between the potential operators and regulators of the disposal facility.

Staffing. In terms of staffing level and the number of jobs that may be associated with the disposal facility, currently SKB has ~480 staff and that this is expected to rise to between 500 and 600. It is envisaged that about 80 of SKB's staff will be located at Forsmark, and that during disposal facility excavation these will be supported by perhaps 500 contractors. Thereafter, of the disposal facility is expected to require a total of ~200 to ~250 staff.

Wednesday 30 November 2011

3. Invited Presentations

On the second day, the workshop received the following presentations:

1. Jeff Williams of the US Department of Energy (US DOE) gave a summary of the status of the US spent fuel disposition programme.
2. Hans Codée of the Central Organisation for Radioactive Waste (COVRA) described the approach to radioactive wastes storage and disposal in the Netherlands.
3. Jürg Schneider of the Swiss National Cooperative for the Disposal of Radioactive Waste (NAGRA) described the Swiss geological disposal programme and the role of radioactive waste storage.
4. Jussi Heinonen of the Finnish Radiation and Nuclear Safety Authority (STUK) described the Finnish disposal programme for HLW and spent fuel.
5. Geraldine Dandrieux of the French Nuclear Safety Authority (ASN) and Jean-Michel Hoorelbeke of the French National Radioactive Waste Management Agency (ANDRA) jointly described the French disposal programme for radioactive waste.

The slides from these presentations are included in Appendix 2. The following paragraphs highlight key points and summarise the associated workshop discussions. During the day there were also two sessions for discussions amongst the working groups.

3.1. Status of the US Spent Fuel Disposition Programme

Jeff Williams gave a summary of the status of the US spent fuel disposition programme. The US has ~104 reactors and a total of ~65,000 tons of commercial spent fuel. Approximately ~15,000 tons of this spent fuel is in dry store, with the rest being in pool storage. At many of the reactor sites, the spent fuel pools are full. There are 54 dry spent fuel stores of various designs distributed across the country in 33 States. The large number of different stores is such that there is a lack of consistency in the storage methods used and, for example, some of the dry stores have casks containing 21 spent fuel bundles that would be difficult to dispose of without re-packaging.

Following the election of Barak Obama, the US programme for developing a geological disposal facility at Yucca Mountain (the YMP) has halted, but the US DOE is still committed to waste disposal rather than indefinite storage. US DOE believes that disposal will be necessary for any future fuel cycle scenario. The US DOE approach is consistent with international recommendations and with the draft recommendation from Blue Ribbon Commission on America's Nuclear Future, which was that "*The United States should proceed expeditiously to develop one or more permanent deep geological facilities for the safe disposal of high-level nuclear waste*".

Discussion

Could the Yucca Mountain Programme re-start? The next US presidential elections are scheduled for 2012, and it is possible that they might affect the YMP, but it is also the case that currently the US Senate and House of Representatives have different views on the Yucca Mountain Programme.

Why not send spent fuel to the WIPP? The US has an operating geological disposal facility for defense-related transuranic wastes called the Waste Isolation Pilot Plant (WIPP), which is situated in bedded salt rocks in New Mexico. It was asked if the WIPP could be used for spent fuel disposal. Theoretically this might be possible, but it was noted that although the WIPP has been certified to receive transuranic wastes, this certification was made by the US Environmental Protection Agency (US EPA) and the WIPP has not been licensed by the US Nuclear Regulatory Commission (US NRC) to receive spent fuel.

Forward programme for disposal. Currently there is no firm proposal from the US DOE of a schedule for developing a disposal facility - it is likely that developing a disposal facility would take at least 20 or 30 years.

Plans for centralised / underground / extended spent fuel storage. Regarding potential centralised or underground spent fuel storage, there are no firm plans for the construction of either centralised spent fuel stores or for underground spent fuel stores. A previous proposal to construct an interim storage facility in Wyoming failed partly because of a lack of trust in a disposal facility being made available. One commercial company has been suggesting development of underground stores, but this is not currently being adopted. It was suggested that given the lack of a geological disposal facility, the US will obviously need an extended period of spent fuel storage. It was explained that the key difficulty is finding a community willing to host a long-term storage facility. If such a community was found it might still take ~10 years to license such a store.

3.2. Radioactive Waste Storage and Disposal in the Netherlands

Hans Codée of COVRA described the approach to HLW and spent fuel storage and disposal in the Netherlands. The Netherlands has:

- One operating nuclear power plant.
- One nuclear power plant that has been shut down.
- Two research reactors.
- A uranium-enrichment plant owned by URENCO.

The volumes of radioactive wastes in the Netherlands are small (~68 m^3 spent fuel & HLW, ~10,000 m^3 LLW, ~10,000 m^3 NORM waste). In the Netherlands, radioactive waste is owned and managed by COVRA. COVRA operates a waste store (known as HABOG) and runs a

modest research and development programme on waste disposal, while investing in a fund that should eventually grow sufficiently to pay for waste disposal.

The HABOG facility includes a dry store for spent fuel with a passive cooling mechanism. The spent fuel is stored in containers and surrounded by argon or other inert gas to prevent corrosion. The HABOG building has been designed to last for over 100 years and to withstand the effects of relevant earthquakes, flooding events and aircraft impacts. The design of the store is such that the waste containers can be inspected. The store design is modular so that it can be extended if needed.

Regarding disposal of radioactive waste, because of the generally high water table and the high population density, there is a lack of suitable land for near-surface waste disposal. COVRA believes that the geology of the Netherlands includes rocks (clay and salt formations) that are potentially suitable hosts for a geological disposal facility. These rocks extend in the direction of Belgium, which is investigating the Boom Clay, and under the North Sea.

COVRA believes that it is not necessary for the Netherlands to develop a disposal facility at this time, and that it is not economic to develop a separate geological disposal facility for the small amount of waste to dispose of

As a consequence, the Netherlands' policy on radioactive waste management is to keep the waste in storage for an extended period (in excess of 100 years), prior to geological disposal, preferably in a disposal facility that would be shared with other disposal programmes. . COVRA, in particular, has been following projects working towards a shared, regional international project, possibly located under the North Sea.

Discussion

Legal framework. . The most relevant documents regarding the Netherlands legal framework and policy for radioactive waste management and disposal are those submitted by the Netherlands to the IAEA in support of the Joint Convention on the Management of Spent Fuel.

Transition from storage to disposal. Hans Codée indicated that as long as there is sufficient money in the fund, once the store is full, a disposal facility will be constructed. It was asked if a disposal facility would need to be constructed and ready to receive wastes immediately after 100 years of waste storage. It was explained that this was not the plan and that it might be that storage would be continued during repository construction so that the total storage time might be 130 years or longer.

Disposal of depleted uranium. Regarding the management of depleted uranium (DU), COVRA does plan to dispose of unwanted DU, but currently UF_6 is converted to U_3O_8 and stored in an unconditioned form so that it might be re-used.

A shared international disposal facility? Questions were asked regarding the acceptability and licensing of a shared disposal facility under the North Sea and that such a facility might be in contravention of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 ('the London Convention'). Hans Codée suggested that even though the law might need to be changed, the proposal for a shared disposal facility under the North Sea ought to be considered because it might be a sensible, economic, feasible and safe solution for the neighbouring countries. The North Sea is already divided up for the licensing of oil and gas extraction. Hans Codée emphasised the point that it would be relatively more expensive to dispose of small volumes of waste in separate national geological disposal facilities than to share an international repository.

Funding for disposal. COVRA charges the waste producers for receiving and storing the wastes. It was asked what COVRA would do if storage costs were to increase. COVRA makes conservative costs estimates and would not impose retrospective charges on waste producers for increased costs. It was suggested that for countries with small nuclear programmes (e.g., five NPPs or fewer), developing a separate national geological disposal facility was not economically viable – this view, however, was strongly contested by other workshop participants, and the general view was that the costs of waste management and disposal should be taken fully into account when considering the costs of a nuclear power programme.

3.3. The Swiss Geological Disposal Programme and the Role of Radioactive Waste Storage

Jürg Schneider of NAGRA described the Swiss geological disposal programme and the role of storage in supporting that programme. Switzerland has five NPPs and since 2006 has not reprocessed its spent fuel.

The Swiss Nuclear Energy Law of 2005 requires that all HLW and spent fuel is disposed of in a geological disposal facility, but also states that allowance has to be made for monitoring for an extended period of time before full closure. There should also be the possibility during this period of waste retrieval *'without undue efforts'*. NAGRA is fully committed to developing such a geological disposal facility.

In Switzerland, a geological disposal repository is regarded as such a strategic national facility that it will need to be approved by both houses of the Swiss Parliament as well as by a national referendum.

The Swiss Federal Government (the Federal Office of Energy) is taking a leading role in the site selection process in Switzerland. The site selection procedure was developed following a broad participatory process and in 2008 the Federal Government published a *'Sectoral Plan'* for deep geological repositories (www.bfe.admin.ch/radioaktiveabfaelle).

According to the Sectoral Plan, site selection will follow a three-stage process:

- Stage 1 (~2.5 years): identification of potential siting regions.
    - Focus: long-term safety and engineering feasibility.
- Stage 2 (~2.5 years): identification of sites for surface infrastructure within potential siting regions and selection of two or more siting regions for more detailed evaluation.
    - Focus: land use planning and environmental impact, and provisional safety analyses for all siting regions.
- Stage 3 (~2.5 to 4.5 years): field investigations and selection of one site, leading to preparation of a safety case for the repository at the selected site and a licence application.

Following site selection, the licensing procedure would involve:

- Preparation of documentation by implementer.
- Authority review.
- Government decision.
- Ratification by parliament.
- Approval at a national referendum.

Until a deep geological disposal repository becomes available, HLW and spent fuel are being stored. This allows the wastes to cool, which will be important because there is a limit to the thermal power of the waste containers that can be disposed of safely when using a bentonite buffer material as is planned in NAGRA's disposal concept.

Waste storage currently takes place at:

- A utility-owned centralised storage facility (the 'ZWILAG' facility).
- A Federal Storage Facility for MIR waste (the 'BZL' facility).
- The NNPs (on-site interim storage of spent fuel / HLW / ILW).

Discussion

Closure of a Swiss geological disposal repository. Regarding the timing of disposal closure, the intention is to backfill the disposal cells immediately following waste emplacement, but to leave the access tunnels open to enable monitoring for an extended period of time before full closure.

Retrievability. Questions were asked regarding the meaning of the term '*retrieval without undue efforts'*. It was acknowledged that this does need to be more fully defined and understood. Nagra is in dialogue with the Swiss regulators over this point.

Site characterisation. It was noted that the Sectoral Plan only seems to allow a few years (possibly less than five years) for characterisation of a geological disposal site. It was

confirmed that this is the case and noted that site characterisation data is already available from previous drilling work in support of hydrocarbon prospecting and other investigations.

3.4. The Finnish Disposal Programme for HLW and Spent Fuel

Jussi Heinonen of STUK described the Finnish disposal programme. Finland has two boiling water reactors (BWRs) at Olkiluoto (operated by Teollisuuden Voima Oyj, TVO), and two VVER units at Loviisa (operated by Fortum Power and Heat Oy). A new European Pressurised Reactor (EPR) reactor is under construction at Olkiluoto, and the Finnish Government has granted 'in-principle' approvals for two further reactors; a fourth reactor at Olkiluoto and one at Pyhäjoki. The new reactor at Pyhäjoki would be operated by a company called Fennovoima Oy.

Finish policy is to dispose of spent fuel directly in Finland without any re-processing. The waste producers (the NPP operators) are responsible for waste management and disposal; there is no centralised or joint national programme for waste disposal.

The HLW and spent fuel are currently stored in pools at the NPP sites, pending development of disposal facilities. The store at Loviisa has already been extended and spent fuel is being stored at increased density. The store at Olkiluoto is being extended. The design lifetimes of the stores are 100 years, although only 20 to 40 years of storage is required to cool the spent fuel sufficiently that it could be disposed of.

The Finnish Government has required Fennovoima Oy by 2016 to submit either an agreement to dispose of spent fuel at the repository being developed by Posiva Oy at Olkiluoto, or a programme for its own separate repository.

Posiva is developing and planning to construct a repository at Olkiluoto according to the KBS-3 disposal concept. Posiva will submit a licence application for the repository to the regulatory authority, STUK, in 2013. The licence application will include an assessment of post-closure repository safety.

Key factors in Finnish waste management have been:

- Long-term political commitment to resolve the nuclear waste issue.
- National strategy and discipline.
- Well-defined liabilities and roles.
- A clear funding system which was established early in the programme.
- Stepwise licensing and implementation, including the right of veto for the community local to the proposed repository.
- Development of regulatory approaches in parallel with research and development, and in analogy with nuclear plant safety regulations.
- Regular regulatory follow-up of progress on the disposal programme.

Discussion

Spent fuel storage arrangements. It was asked whether there were any plans to move from pool storage to dry stores, particularly considering the events at Fukushima. Although dry stores might feature at the new NPPs, the need or pressure to change from pool storage at the existing plants is currently not strong. In part this is because of the good progress being made towards implementing disposal. However, some tighter requirements have been placed on the Olkiluoto storage extension - the pools and coolant supply must be protected against the impact of a large airplane crash. Underground storage options were not considered at the time of the decisions to extend the stores at Loviisa and Olkiluoto.

Disposal programme schedule and regulatory oversight. Concerning the definition in legislation of dates for key milestones in the disposal programme, It was explained that the Finnish Government had defined the key steps in the programme, but had not specified dates in legislation. Dates are, however, specified in lower-level guidance documents. Finnish law requires regulatory oversight of Posiva's programme by STUK, who advise the relevant ministry on a three-yearly cycle. The regulatory locus for STUK's oversight is established in the Government's Decision-in-Principle.

3.5. The French Disposal Programme for Radioactive Waste

Geraldine Dandrieux of The French Nuclear Safety Authority, ASN and Jean-Michel Hoorelbeke of ANDRA jointly described the French HLW and spent fuel disposal programme. Key points included:

- France has a significant and complex nuclear programme with a wide variety of wastes.
- French Law forbids the disposal in France of wastes from other countries.
- The waste producers have to set aside funds for waste disposal.
- The Government has to update a National plan on management of radioactive materials and waste every three years.

The French 2006 Planning Act on the sustainable management of radioactive materials and waste requires research and development on:

- Interim storage.
- Waste disposal.
- Partitioning and Transmutation (P&T) of wastes from 'Generation IV' reactors.

ANDRA is planning to submit a licence application for a geological disposal facility in 2014, with a view to beginning operation in 2025. This application will include a safety case for disposal with an assessment of post-closure safety. ASN, with the technical support of the French Institute for Radiological Protection and Nuclear Safety (IRSN) will review the application in the 2015-2016 timeframe.

ANDRA is conducting a significant research and development programme, which includes consideration of the 'industrialisation' of disposal, and of waste retrievability. The disposal facility would be closed after a so called 'retrievability phase'. ANDRA recognises the risks associated with leaving a disposal facility in an un-closed, abandoned state, and is not planning that the disposal would be left open.

Interim storage of wastes is seen as a necessary complement to disposal. For spent fuel, 50 to 60 years of interim storage will be required for cooling prior to disposal, but if the storage period were extended to 90 years, then it might be possible to dispose of the spent fuel with less spacing and thereby reduce the volume of rock required for disposing of the waste.[1]. P&T, which is still in a research and development phase, might also make it possible to reduce the thermal load placed by the waste on the disposal.

Discussion

Research and safety assessment programme. The need for research and development and safety assessment to continue in the period after the licence application has been discussed. ANDRA plans to continue with R&D and safety assessment throughout disposal development programme.

Reversibility, retrievability and abandonment. There was discussion of the meanings of and plans for reversibility and waste retrievability:

- Reversibility is not fully defined in the French programme, but refers to the ability to go back on (reverse) previous steps and decisions in the waste management process. A waste management programme or project that is readily reversible possesses flexibility.
- ANDRA was questioned as to why it seems to place so much emphasis on waste retrievability. Some workshop participants suggested that putting too much emphasis on retrievability might be seen as a lack of confidence in the safety of the disposal system. Jean-Michel Hoorelbeke explained that ANDRA is planning to provide reversibility and waste retrievability during repository operations – a period of some 100 years – and that this does not compromise long-term repository safety.
- With regard to the possibility of the disposal facility being abandoned in an un-closed state, it was noted that local stakeholders were concerned about what might happen to a disposal facility after the operator leaves the site, and consequently some want post-closure monitoring. ASN noted that it will require the disposal facility to be closed on a fixed date because of concerns over the safety of an abandoned un-closed repository.
- ANDRA is planning a full scale test / demonstration of repository sealing and closure.

[1] Note that extending the storage period beyond approximately 90 years would not bring any significant further benefit in terms of reducing the size of the repository because the rate of cooling decreases and because of the in-growth of americium.

Thursday 1 December 2011

4.1. Working Group Discussions and Presentations

During the first two days of the workshop, three sessions were held in which the participants divided into small working groups to consider key topics associated with HLW and spent fuel storage and disposal. Five working groups were convened and all groups addressed the same set of topics. Each working group was led by a volunteer from the workshop participants as follows:

Working Group A	Bengt Hedberg of SSM, Sweden.
Working Group B	Glenn Round of Ontario Power Generation (OPG), Canada.
Working Group C	Christophe Serres of the Institute for Radiological Protection and Nuclear Safety (IRSN), France.
Working Group D	Kaisa-Leena Hutri of STUK, Finland.
Working Group E	Paul Degnan, IAEA.

The role of the working group leaders was to facilitate and organize the discussions and to present the results of the discussion back to the full workshop on the last morning.

The working group topics had been defined by the IAEA and were as follows:

1. The establishment and implementation of comprehensive radioactive waste management strategies.
2. The safety implications of longer periods of waste storage and how long-term storage can be safely envisaged.
3. The importance of international cooperation for the storage and disposal of spent fuel and HLW.
4. The link between the availability of geological disposal facilities for spent fuel and HLW and the period of waste storage.
5. The implications of longer periods of waste storage on knowledge transfer.

The following paragraphs provide a summary of key points from the Working Group's presentations. The points have been compiled from across the five working group's presentations as there was a large degree of consensus between the groups. The presentation slides used by the working group leaders are contained in Appendix 2.

Topic 1 The establishment and implementation of comprehensive radioactive waste management strategies

The working groups considered that:

- There is a need for each country with radioactive waste to establish a comprehensive legal and policy framework for radioactive waste management and disposal. This should define the overall objectives of waste management and the necessary organisational responsibilities (e.g., for ownership of the wastes, for storage of the wastes, for disposal of the wastes, for regulation and licensing). Ideally, such arrangements should be established at an early stage, when a nuclear power programme is begun.
- Waste storage is not sustainable or defensible in the very long-term without an associated waste disposal programme because indefinite waste storage would place undue burdens on future generations. Waste storage and disposal are complementary; disposal is an essential component of the waste management system, and the waste management system should be considered as a whole in an integrated way.
- Each country with radioactive waste should have a national waste management and disposal programme or plan, with clearly-defined, realistic milestones and scheduling. Geological disposal programmes typically take several decades and, thus, work towards disposal should begin early, and should not be delayed on the basis of a policy of interim waste storage.
- There is no single universal model for gaining acceptance for the various components of the nuclear power or waste management programme. Key aspects of successful programmes include consistent political will and support, adequate funding, years of dialogue with local communities to build trust, confidence and acceptance of NPPs and waste management facilities, strong regulation and periodic safety reviews, and arrangements for long-term knowledge management and the maintenance of skills.

Topic 2 The safety implications of longer periods of waste storage and how long-term storage can be safely envisaged.

The working groups noted that extended storage periods bring increased risks with respect to the need for active rather than passive control and maintenance systems, and the possible effects of societal change, instability, war etc. Extended storage times also increase costs and financial risks. For these reasons it may be harder to ensure the safety and security of the waste materials for long periods in surface stores than in a closed underground disposal facility.

With regard to the idea of waste storage in an underground facility, the working groups noted that this is possible, but they considered that the facility ought to be shown to be

capable of meeting the same requirements as would be needed to obtain a geological disposal facility licence. Without this requirement, there was concern that if wastes in an underground store were abandoned, the store might *de facto* become a disposal facility that would not necessarily provide acceptable levels of safety.

Designing and implementing geological disposal so as to provide the possibility of waste retrieval can be helpful in terms of public acceptability, but the working groups considered that retrievability provisions should not be allowed to compromise the safety of the disposal facility.

The working groups suggested that although there are uncertainties, the costs of maintaining a repository in an open state might be greater than the costs of waste retrieval by excavating repository seals and backfills, and that, therefore, there might not be technical or economic reasons to keep a geological waste disposal facility open after waste emplacement.

Waste management organisations should explain clearly their intentions to store, dispose of, and / or possibly retrieve wastes from the facility. Some workshop participants felt that the durations of the period of storage and of any period of retrievability should be clearly defined at the outset.

Topic 3 The importance of international cooperation for the storage and disposal of spent fuel and HLW.

There is considerable international cooperation on the management of HLW and spent fuel, and other radioactive wastes, in terms of sharing information, discussing approaches (e.g. to safety assessment) and in conducting large-scale tests and trials of repository engineering. Such cooperation is encouraged and facilitated by the IAEA, the NEA and the EC.

Countries with new or small nuclear power programme and small volumes of waste have particular concerns. Such countries can gain from the broad literature that is available on radioactive waste management and from participating in international research and development projects. However, the working groups considered that at some point, each waste management programme would have to conduct its own research and development work to progress waste management solutions that meet its national requirements and characteristics.

There was much discussion of the possibilities for the establishment of international disposal facilities that might be shared between two or more countries or waste management programmes. There were many questions regarding whether and how such cooperation might be established. There was general consensus that in order for such international waste disposal solutions to succeed, there would have to be high-level Governmental agreements and long-term commitment. The transfer of wastes between countries would have to be legal and relevant safeguards would need to be in place. There

would also need to be agreement on organisational responsibilities and regulatory oversight.

The working groups considered that work towards an international disposal facility should not replace work towards a national waste management and disposal solution.

It was also noted that in EC countries, the EC Directive on the Responsible and Safe Management of Spent Fuel and Radioactive Waste will place increasing emphasis on international peer reviews. The working groups suggested that it would be helpful if there were standardised approaches to such peer reviews.

Topic 4 The link between the availability of geological disposal facilities for spent fuel and HLW and the period of waste storage.

The working groups noted that in very general terms, the need for waste storage increases if disposal facilities are not available. However, once a disposal facility is available then, the period of waste storage required depends on various technical factors such as the need for convenience of waste handling and transport ('buffer storage'), and the need for cooling (reduction in the thermal power) of the wastes to levels such they can be received for disposal in a repository. Various possibilities exist for managing the thermal load in a geological disposal facility, including controlling waste container loadings, controlling the waste container spacings and the layout of the repository, and selecting repository materials with certain thermal conductivities and susceptibilities to thermal degradation.

There may also be non-technical links between the availability of geological disposal facilities and the period of waste storage. Examples were discussed at the workshop in which the acceptability to local populations of interim waste storage facilities depended strongly on the degree of confidence that was placed in disposal facilities becoming available.

Overall, the working groups suggested that the period of waste storage should be determined by the needs of the waste management and disposal system as a whole. The storage period should neither be minimised nor longer than needed.

Topic 5 The implications of longer periods of waste storage on knowledge transfer.

The working groups identified the following possible implications of longer waste storage periods:

- Staff and experience loss through retirement.
- Increased needs for staff succession planning, staff training, and competency maintenance.
- Increased needs for long-term records maintenance and archival, but also for communication of information to future generations.

- The possible need for funding of waste management and knowledge management activities after the end of the nuclear power programme.

It was noted that these points would apply to regulatory organisations as well as to waste management organisations.

4.2 Panel Discussion

Following the presentations by the working groups, Johan Anderberg (SSM) and Magnus Vesterlind (IAEA) initiated a general discussion amongst the workshop participants. The discussion was assisted by an invited panel comprising key members of the workshop organising bodies and the presenters of the invited papers. Johan Anderberg noted that there seems to be strong consensus that geological disposal is the essential target of HLW and spent fuel waste management. Waste storage may be a step on the path to waste disposal.

Magnus Vesterlind (IAEA) noted that:

- There had been good participation and dialogue at the workshop.
- A consistent message from the workshop participants was that HLW and spent fuel waste disposal is essential, following waste storage as needed.
- Different situations in different countries may mean that the timing of waste disposal varies.
- Work towards developing and implementing waste disposal solutions should not be delayed or postponed on the basis of arguments that the wastes can be stored safely.
- There is a need to recognise that many countries are starting to consider and develop waste management and disposal programmes.
- Waste management and disposal should be addressed at the start of a nuclear power programme.

Points raised during the following discussion included:

- Several new waste management and disposal programmes are beginning, particularly in some of the smaller Asian countries. These programmes would welcome greater interaction with more advanced waste management programmes.
- In some parts of the world, political changes can be rapid and these changes can badly affect waste management plans and programmes – there is a need to isolate waste management from such shorter-term political changes.
- Experience has shown that there are risks associated with trying to rush geological disposal programmes. Rather than rushing to dispose of the wastes as a way of avoiding political change, it may be better to work towards waste disposal in a steady consistent fashion, while engaging with local populations and stakeholders.

- It is essential to have a clear legal and policy framework for waste management and disposal, with clear responsibilities, independent regulation and periodic reviews. These can offer some protection for waste management and disposal programmes against short-term political change.
- It is important for a waste management and disposal programme to remain flexible so that it can respond to political changes, criticisms and new challenges.
- It is essential to make sure that there is sufficient funding for waste management and disposal, and its regulation; this need should be recognised at the outset, and financial responsibilities for waste management (and decommissioning) should be clearly acknowledged. A clear funding strategy is needed.
- It is easy and quick to lose stakeholder trust, but very slow to re-build trust. It is essential, therefore, to be open and transparent about the need for geological disposal.
- Safeguards and security measures need to be fully implemented during waste storage and disposal facility operation, but such measures should not be needed after repository closure.
- With regards to the transfer of HLW and spent fuel between countries, there is a moral obligation to check that the country receiving the wastes has a disposal solution that meets accepted safety standards.
- Deep borehole disposal methods have been suggested for some wastes, but these methods have not been tested sufficiently and their safety has not been demonstrated. It is also more difficult to verify and monitor the correct implementation of borehole disposal.
- Experience in trying to gain broad acceptance for radioactive waste disposal suggests that it is important to emphasise the ability to monitor a geological disposal facility, and to be able to retrieve the wastes. It is important, however, that geological disposal facilities are closed physically and not abandoned in an unclosed state.
- The provision of local community benefits packages or compensation funds can be one way of increasing acceptance of waste management facilities. It is good practice to apply such funds for enhancing and developing the local area, for example by providing jobs and educational and/or training facilities, rather than for offsetting taxes.
- international efforts to collate knowledge and review experience on the siting of geological disposal facilities, and identify any lessons learnt.

5. Workshop Conclusions

As Chair of the Workshop, Walter Blommaert (FANC) summarised the key conclusions. The workshop had been a significant success in terms of attracting a wide range of participants from many countries, and in terms of the very good level of interaction and constructive discussions that had been held. The workshop discussions confirmed the following key points:

- There is a need for each country with radioactive waste to establish a comprehensive legal and policy framework and implement a programme for the management and disposal of radioactive wastes with clear objectives and realistic milestones.
- Waste storage and disposal are complementary components of a comprehensive waste management and disposal programme; indefinite storage of waste is not an acceptable or sustainable alternative to disposal.
- Knowledge management in its broadest sense should be an important activity in a radioactive waste management and disposal programme, particularly because of the long timescales needed for waste storage and disposal facility implementation.
- It is important to take account of the ageing of wastes and associated materials comprising the storage and disposal system – this requires the conduct of a range of scientific studies within a reasoned research and development programme.
- Stakeholder involvement and dialogue, together with programmatic flexibility are important in gaining acceptance for waste storage and disposal facilities.

Walter Blommaert (FANC), Magnus Vesterlind (IAEA) and Johan Anderberg (SSM) closed the Workshop by thanking the participants, speakers, working group leaders, and organisers of the workshop.

AGENDA

International Workshop on High Level Radioactive Waste and Spent Fuel Management – Storage and Disposal
Stockholm, Sweden 29 November – 1 December

Technical Visits: 28 November & 2 December

Chairman: Walter Blommaert, FANC Belgium

Scientific Secretary: David Bennett, UK

Workshop Venue: Conference Center Näringslivets Hus, Stockholm (www.naringslivetshus.se)

TUESDAY, NOVEMBER 29

Introduction

9:30 Opening and Welcoming Addresses

- Johan Anderberg, Director Radioactive Materials, Swedish Radiation Safety Authority (SSM) – 10 Min.
- Magnus Vesterlind, Head Waste and Environmental Safety Section, IAEA – 10 Min.
- Chairman's introduction & Administrative arrangements

Keynote presentations

10:00 Hans Riotte, OECD/NEA: International Overview of Storage and Disposal Status – (30'+15')

10:45 – 11:15 COFFEE BREAK

11:15 Ute Blohm-Hieber, EC DG ENER: The European Directive on the Management of Spent Fuel and Radioactive Waste (30' +15')

12:00 – 13:30 LUNCH

13:30 Olle Olsson, SKB Sweden: The SKB Spent Fuel Disposal Project – License Application (30'+15')

Working group session

14:15 Introduction of working groups and instructions (15')

14:30 – 14:45 COFFEE BREAK

14:45 – 17:00: Working Groups

WEDNESDAY, NOVEMBER 30

8:30 Jeff Williams, US DOE: Status of US Spent Nuclear Fuel disposition Programme (30'+15')

9:15 Hans Codee, COVRA, The Netherlands: The storage and disposal approach in the Netherlands (30'+15')

10:00 – 10:15 COFFEE BREAK

10:15 Juerg Schneider, NAGRA, Switzerland: The Swiss geological programme and the role of storage (30'+15')

11:00 – 12:00 Working groups

12:00 – 13:30 LUNCH

13:30 Jussi Heinonen, STUK Finland: The Finnish Disposal Programme (30'+15')

14:15 Geraldine Dandrieux ASN, France & Jean-Michel Hoorelbeke, ANDRA France: The French Disposal Programme (30'+15')

15:00 – 15:15 COFFEE BREAK

15:15 – 17:00: Working groups

THURSDAY, DECEMBER 1

9:00 Working group debriefings (10'/WG)

10:00 – 10:30 COFFEE BREAK

10:30 – 11:30 Panel discussion

11:30 – 12:00 Concluding remarks and closure: Chairman, IAEA, SSM

Working Groups:

- 5 working groups will be organized with one leader per working group
- The role of the working group leader will be to facilitate and organize the discussions and to report on the last day, prior to the panel session
- All working groups will address the same topics - 5 topics are planned
- In order to facilitate the discussions within the working groups a series of statements or questions will be provided for each topic
- Planned leaders for the working groups:
    - Bengt Hedberg, SSM Sweden
    - Kaisa-Lena Hutri, STUK Finland
    - Christophe Serres, IRSN France
    - Paul Degnan, IAEA
    - Glenn Round, OPG, Canada

Panel Composition

- Panel leader/moderator: Johan Anderberg (SSM, Sweden)

The lecturers

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Appendix 2 Workshop Presentations