# Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

# National Report from Denmark

## Third Review Meeting, 11 - 22 May 2009

National Board of Health
National Institute of Radiation Protection
October 2008

*Cover picture: Danish Reactor 2 at the Risø Peninsula.*

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## Section A. Introduction

Denmark signed the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management 29 September 1997, the day it opened for signature. The Convention was accepted 3. September 1999 by letter from the Foreign Ministry to the International Atomic Energy Agency (IAEA). Until further notice the Convention does not apply for the autonomous territories Greenland and the Faroe Islands.

The present report is the Danish National Report for the Third Review Meeting to the Convention. The meeting takes place 11-22 May 2009 at IAEA, Vienna. As described in the Guidelines regarding the Form and Structure of National Reports, (INFCIRC/604 rev. 1, 19 July 2006) duplication within the reporting, including duplication from former reports, should be avoided. At the same time it is stated that the report should be a stand-alone report. Consequently, Denmark has in this report decided to focus on what is considered highlights and new developments since the National Report from the Second Review Meeting. However, the present situation will, if considered necessary from a stand-alone report point of view, be stated briefly under each paragraph, even if there has been no development since the last meeting. For the reader who wishes a more detailed description of the Danish practices and understanding of the development before 2006, the former reports as well as the questions and answers can be found via the homepage for the Joint Convention[1].

Main developments since the 2006 meeting fall within two areas of work: 1) the decommissioning of the three Danish research reactors and 2) the establishing of a final repository for LILW (Low and Intermediate Level Waste).

DR 1 (Danish Reactor 1) is now fully decommissioned and released from regulatory control. DR 2 is also fully decommissioned, but the reactor building has not been released from regulatory control as it will be used for storage purposes etc. in connection with the decommissioning of DR 3. With respect to DR 3, the fuel elements are removed, decommissioning of auxiliary systems is in progress, and complete decommissioning to »green field« is under planning.

With regard to the process of establishing a final repository, a “Basis for Decision” describing how to proceed with the project has been prepared. The “Basis for Decision” has been forwarded to the Government and it is expected that the process to start locating a site will be endorsed by the Parliament in the fall of 2008.

The present report also considers the issues raised in the Rapporteur’s Report for Denmark in the 2006 meeting, where the following themes were highlighted as challenges:

- Disposal facility for low and intermediate level waste (site selection, design, licensing)
- Human resources - Nuclear Regulatory Authorities
- Complete decommissioning of research reactors
- Finding a solution for disposal of the small quantity of spent fuel
- Nuclear Regulatory Authorities (inspections of waste storage facilities, survey for orphan sources).

The report is prepared by the National Institute of Radiation Protection under the National Board of Health, in co-operation with Danish Decommissioning (DD) and the Nuclear Division under the Danish Emergency Management Agency. It is concluded in the report, that Denmark meets all obligations of the Convention.

[1] http://www-ns.iaea.org/conventions/waste-jointconvention.htm

## Section B. Policies and Practices

No new developments. Please refer to the second National Report, 2005[2].

The policy and practice for radioactive waste management is to collect, manage and store all Danish radioactive waste under safe and secure conditions at dedicated storage facilities at the organisation Danish Decommissioning.

The availability of adequate financial resources is assured also in the future, inasmuch as Danish Decommissioning is government property under the administration of the Danish Ministry of Science, Technology and Innovation. Thus the financial capacity to maintain and if necessary improve the safety of facilities for spent fuel and radioactive waste management in accordance with the regulatory requirements is ensured.

## Section C. Scope of Application

As Contracting Party to the Joint Convention Denmark has declared that:

- Reprocessing is not part of the spent fuel management
- Waste that contains only naturally occurring radioactive materials is not radioactive waste for the purpose of the Convention
- Spent fuel or radioactive waste within military or defence programmes is not spent fuel or radioactive waste for the purpose of the Convention.

However, the management of radioactive waste that contains only naturally occurring radioactive materials and all radioactive waste from the Danish military is identical to the management of radioactive waste described in this report. This kind of waste is also covered by the legislative and regulatory system mentioned in section E and in the previous National Report from Denmark, 2005.

## Section D. Inventories and Lists

*Article 32. Reporting*

### Spent fuel management facilities

There is no new development regarding spent fuel. The present situation is described below.

There are no spent fuel management facilities in Denmark subject to the Convention. However, minor amounts of spent fuel are stored, under safe and secure conditions with appropriate surveillance, at the storage facilities for radioactive waste at Danish Decommissioning.

Special precautions for heat generation and dissipation are not necessary for these materials. An inventory of the stored spent fuel is given in table 1.

### Radioactive waste management facilities

An overview of Danish Decommissioning nuclear facilities and associated buildings is given in figure 1. Two new minor facilities have been included since the previous report: 1) A small isolated facility for safe and secure storage of radioactive liquids located near the Waste Management Plant (figure 1) as well as 2) A decontamination cabinet equipped with high pressure water cleaners and glass blasting tool (figure 2) located in the building complex around DR 3

[2] National Report from Denmark, 2005:
http://www.sst.dk/publ/Publ2005/SIS/Joint_Convention/Joint_Convention_Report_2005.pdf

*Table 1. Inventory of spent fuel. Activities refer to January 2008.*

| Spent fuel | Storage facility | Material | Mass/ Volume | Activity |
|---|---|---|---|---|
| Spent fuel from DR 1 | DR 3 building complex | Solution of 20% enriched uranyl sulphate in light water | 15.8 l | 112 GBq fission products<br>4 GBq actinides |
| Experimental irradiated spent fuel of power reactor type | Centralvejs-lageret | Uranium oxide pellets mostly in zircalloy tube | 233 kg | 703 TBq fission products<br>32 TBq actinides |

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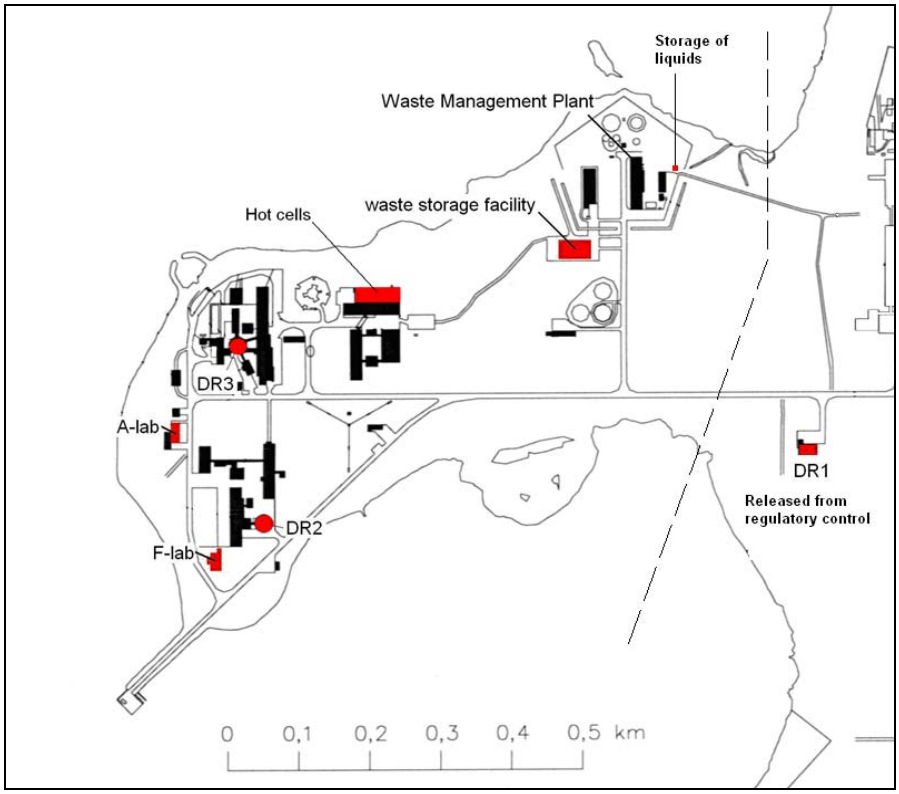


*Figure 1. Nuclear facilities and associated buildings at Danish Decommissioning, Risø Peninsula. Buildings mentioned in text are highlighted in red. Division line (stipple) between evacuation zones has changed as consequence of changed DR 1 status.*

Furthermore, the storage facility for LILW has been extended to accommodate more waste. The extension is a simple prolongation of the existing building and increases the area with 193 $m^2$, which can accommodate approx. 1,200 extra drums with LILW. The extension was opened March 2008.

The commissioned laboratory (A-lab) for sampling and characterisation of materials from facilities, buildings, and areas was inspected and approved by the Nuclear Regulatory Authorities ultimo 2005 shortly after submission of the previous National Report.

In 2006 the laboratory (F-lab) for clearance of decommissioning waste was approved by the Nuclear Regulatory Authorities with respect to a restricted and well defined amount and type of decommissioning waste. There are no restrictions on the amount or type of decommissioning waste for handling in F-lab after the independent accreditation of the lab in 2007.

Since the publication of the previous National Report the waste flow has developed considerably with respect to both amounts and routes. A significant amount of waste has passed

the clearance criteria and has been released from regulatory control since the F-lab went into operation. High waste production rates are naturally linked to the dismantling of the reactors DR 1 in 2005 and DR 2 in 2007.

*Figure 2. Decontamination cabinet for high pressure water or glass blasting.*

An inventory of radioactive waste that is subject to the Convention is given in table 2 for conditioned waste and in table 3 for unconditioned waste. Table 4 shows recently produced operational and secondary waste (not decommissioning waste) as well as unconditioned waste as received from external producers.

*Table 2. Inventory of conditioned radioactive waste stored at DD. All radioactive waste is classified as low and intermediate level waste - short lived (LILW-SL). Activity refers to year 2008.*

| Storage | Volume ($m^3$) | Activity (TBq) |
|---|---|---|
| Storage Hall | 1,200 | 5 |

*Table 3. Inventory of unconditioned radioactive waste stored at DD. All radioactive waste is classified as low and intermediate level waste - long lived (LILW-LL). Activities refer to year 2008.*

| Storage | Mass (tons) | Activity (TBq) |
|---|---|---|
| Drum Store and 'Centralvejs-lageret' | 125 | 430* |
| Taillings and ore | 4,800 | 0.1 |
| 'Mellemlageret' | 173 | 2** |

** Including 18 TBq LL β/γ-emitters and 4 TBq α-emitters*
** Estimated

*Table 4. Unconditioned waste produced/received (decommissioning waste not included).*

| Year | 2005 | 2006 | 2007 |
|---|---|---|---|
| Operational waste and secondary waste (tons) | 2.2 | 0.2 | 0.8 |
| Waste received from external waste producers (tons) | 2.3 | 2.5 | 2.2 |

**Nuclear facilities under decommissioning**

One of the issues that were highlighted as a challenge in the 2006 Rapporteur's Report was the nuclear facilities. The decommissioning is proceeding according to plan and the progress is described in the following.

There are no additional facilities under decommissioning relative to the previous report. However, there has been a considerable development since then.

Most notably the smallest reactor DR 1 is fully decommissioned and the building has been released for other non-nuclear purposes. Also DR 2 is fully decommissioned, but the reactor building has not been released from regulatory control, as it is anticipated to use the reactor building and building crane for handling of large/heavy objects from the upcoming decommissioning of DR 3. The secondary cooling system of DR 3 has been removed.

The plan for decommissioning of Hot Cells has been approved by the authorities in early 2008 and the decommissioning is in progress.

As requested in the Rapporteur's Report for Denmark in 2006, a more detailed account of the latest developments and status in the decommissioning process are given in table 5 and the subsections below.

*Table 5. Nuclear facilities under decommissioning (updated August 2008).*

| Nuclear facility | Type | Taken out of operation | Decommissioning status |
|---|---|---|---|
| DR 1 | Small homogeneous 2 kW reactor mainly used for educational purposes | 2001 | Fully decommissioned and released from regulatory control in 2006. |
| DR 2 | 5 MW research reactor of the swimming pool type | 1975 | Reactor fully decommissioned, but the building will be used for storage of DR 3 waste objects prior to final release from regulatory control. |
| DR 3 | 10 MW heavy water research reactor of the PLUTO type | 2000 | Fuel elements removed. Decommissioning to »green field« is under planning. Secondary cooling system and structures dismantled. Decommissioning of peripheral systems ongoing. |
| Hot Cells | Facility for post irradiation investigations of nuclear fuel | 1989 | The decommissioning plan was approved by the authorities in spring 2008 and the dismantling began summer 2008. |
| Fuel fabrication | Fuel fabrication facilities for DR 2 and DR 3 | 2002 | Decommissioning to »green field« is under planning. Equipment removed. Certain contamination- and radiation risk zones down-graded. |

**Danish Reactor 1**

After regulatory approval of the specific decommissioning plan in mid 2004, DR 1 was successfully dismantled and demolished in 2005. On the basis of a detailed final decommissioning report[3] presented by Danish Decommissioning in late 2005, the Nuclear Regulatory Authorities finally released the building and area from regulatory control in early 2006.

As the approved overall decommissioning strategy is to dismantle the least radioactive facilities first in order to build up experience and skills, DR 1 was the first of the three Danish reactors to be decommissioned. It was a small homogeneous 2 kW reactor mainly used for educational purposes, and it thus provided an opportunity to implement and exercise decommissioning techniques on a small scale reactor with radiological safety risks on a corresponding scale.

After the preceding characterisation, the decommissioning was carried out in a sequential manner; with dismantling of auxiliary and secondary systems (control house, rods, CCA, etc), followed by the primary systems (graphite, core vessel, recombiner etc.) and demolition of the reactor block and floor. Clearance measurements then followed, lasting approximately 3 months.

By dismantling reactor DR 1 and demolishing its concrete structures Danish Decommissioning produced approximately 38 t radioactive waste (primary waste), including: 31 t concrete, 4.1 t graphite, 1.7 t steel and 1 t miscellaneous materials. The process furthermore generated 2.2 t radioactive waste from the operation itself (secondary waste), and 30 t waste awaiting measurements for eventual clearance.

In accordance with the operational limits and conditions and IAEA recommendations, Danish Decommissioning provided a lessons learned report to the Nuclear Regulatory Authorities as well as for internal and external use in general. Among the lessons learned by the decommissioning of DR 1, Danish Decommissioning reported the following waste handling issues, which emphasize the importance of good planning and documentation:

- Decommissioning operations, which comprise numerous types of waste, often call for additional manpower in order to handle and store the produced waste as well as to maintain the required waste characterisation and documentation.
- Digital photos can often be of considerable assistance in the documentation process.
- With respect to the waste packaging; maintaining a high waste density and the required separation of various waste types in the waste containers requires considerable planning in advance of the actual demolition.
- The use of extra equipment such as disposable clothes, gloves, plastic covers etc. in order to confine the dispersion of radioactive particles often leads to considerable amounts of secondary waste.

**Danish Reactor 2**

After regulatory approval of the specific decommissioning plan in late 2005, DR 2 was successfully dismantled and demolished from 2006 to early 2008 (figure 3). A final decommissioning report will be submitted by Danish Decommissioning to the regulatory authorities in 2009 at the latest. However, as a consequence of the anticipated use of the building for handling and storage of large waste objects from the dismantling of DR 3, the building and surrounding area will not be released from regulatory control until the final stages of the decommissioning of DR 3.

[3] Decommissioning of DR 1, Final Report, DD-18(EN), Danish Decommissioning, 2006 (http://www.dekom.dk)

*Figure 3, (Upper left) DR 2 from above, (upper right) Destruction of concrete shield, to avoid spreading of dust a tent, with low pressure inside, was raised around the reactor, (lower left) Destruction of DR 2 reactor block, (lower right) After the reactor block is removed only a 16 m² hole remains.*

DR 2 was selected as the second decommissioning target in line with the overall decommissioning strategy. DR 2 was a 5 MW pool type research reactor. It was operational for only 16 years and was permanently shut down in 1975. Dismantling of auxiliary systems as well as enhancement and sealing of the reactor block/top shielding were carried out in the late 70's. During this process reactor components which could be straightforwardly removed, were stored in the appropriate waste storage units at the Waste Management Plant, leaving the reactor considerably less active.

A detailed radiological characterisation was carried out during the years 2000-2003 and was later followed by the dismantling of various systems and the reactor shield in a sequential manner, which in principle was similar to the dismantling of DR 1.

Approximately 23 t decommissioning waste samples were analysed at the F-lab in 2007. In total, Danish Decommissioning generated 175 t radioactive primary waste for storage and cleared 421 t primary waste (concrete and steel) for release from regulatory control in con-

nection with the decommissioning of DR 2. During the process Danish Decommissioning produced about 0.8 t radioactive secondary waste. An exact account of the various waste categories as well as a lessons learned account will be published in the final decommissioning report for DR 2.

**Danish Reactor 3**

DR 3 was a 10 MW, heavy water moderated research reactor of the PLUTO type. It was in operation from 1960 to early 2000, and was shut down permanently in late 2000. DR 3 is now in the initial phases of decommissioning as dismantling of certain auxiliary systems was approved in late 2007. However, a comprehensive decommissioning plan for the entire DR 3 is still in preparation. DR 3 has previously been subject to a number of dismantling operations with high similarity to routine maintenance operations or assembling/disassembling the various experimental rigs. These dismantling operations include:

- Shipping of spent fuel to USA in accordance with the initial agreement with the supplier of the fuel (USA)
- Dismantling of experimental set-up frames and housing, back-up power units, cooling systems and CCA operational and maintenance area, as well as redundant offices
- Storage of dismantled CCA, isotope rigs, instrumentation
- Preservation of circuits and auxiliary systems (safe condition)
- Construction of appropriate shielding in forthcoming decommissioning areas
- Demolition of cooling tower foundation (cooling tower dismantled previously)
- Tapping and evacuation of $D_2O$ system.

It should also be mentioned that radiological characterisation of DR 3 and the contents of various basin storage positions has been carried out and that the heavy water from DR 3, previously stored at the DR 2, has been exported to Canada in 2007 for reuse.

**Hot Cells**

The Hot Cell facility was in active use during the period 1964 – 1989 (figure 4). The six concrete cells were used for post-irradiation examination of fuel pins irradiated in the DR 3 reactor, the Halden reactor in Norway and other reactors. Power reactor fuel pins, including plutonium enriched pins, from several foreign reactors have been examined. All kinds of non-destructive and destructive physical and chemical examinations have been performed. In addition, various radiotherapy sources – mainly $^{60}Co$ sources - have been produced.

As a result of the cutting and destructive testing of irradiated fuel and other irradiated material dust containing fission and activation products were released in the cells and settled on workbenches and other surfaces. Hence $^{90}Sr$ and $^{137}Cs$ as well as a number of transuranic α-emitters are still present in the cells. In addition the work with $^{60}Co$ radiotherapy sources has resulted in a number of Co pellets being dropped and not retrieved again; they thus appear as hot spots on workbenches and floors.

In 2007 characterisation of the cells was carried out from the top of the cells. These data, along with older measurements from 1990, were used to develop a project plan for the decommissioning of the facilities. The project plan was approved by the national regulatory authorities in the spring of 2008. The decommissioning is planned to commence in the fall 2008 after deadline of this report.

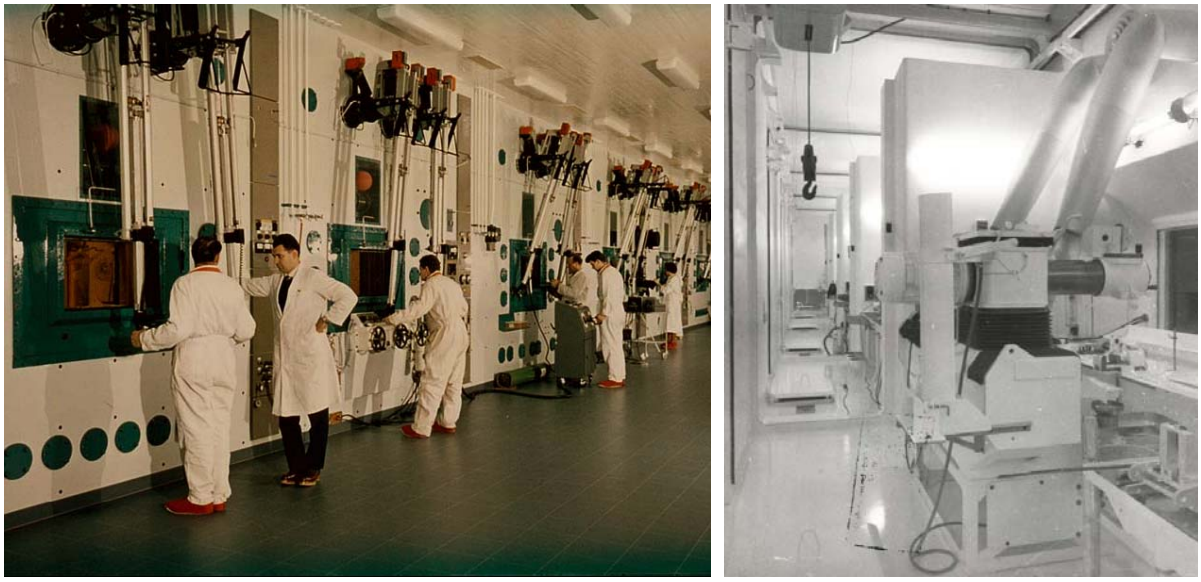

*Figure 4. (left) The operating hall with the front of the six concrete cells in the sixties and (right) A view into the cells before the facility was taken into operation.*

**International expertise and decommissioning**
Two representatives from Danish Decommissioning and the Nuclear Regulatory Authorities participate in the IAEA International Project on Evaluation and Demonstration of Safety for Decommissioning of Nuclear Facilities (DeSa). The project draws on international experience in order to develop a harmonized approach for evaluating the safety of decommissioning activities and reviewing safety assessments for these activities.

Three safety reports have been developed, each providing a test case from which a detailed decommissioning project can be planned. The decommissioning of DR 1 provides one of the test cases. A considerable number of international experts have thus scrutinised the various phases of the decommissioning of DR 1, leading to further evaluation and improvement of decommissioning and waste handling plans with respect to the remaining nuclear installations in Denmark. Both Danish participants took part in the development of the DR 1 test case.

## Section E. Legislative and Regulatory System

*Article 18. Implementing measures*
*Article 19. Legislative and regulatory framework*

In October 2007 a new Order on sealed radioactive sources came into force (Order No. 985 of 11 July 2007). The new Order replaces the old orders on the use of sealed radioactive sources in industry, hospitals, laboratories etc. and on industrial gamma radiography installations. The new Order introduces new requirements on security of sealed radioactive sources in Denmark based on recommendations from the International Atomic Energy Agency (IAEA-TECDOC-1355). The Order implements all provisions in EU Council Directive 2003/122/Euratom of 22 December 2003 on the control of high-activity sealed radioactive sources and orphan sources and the IAEA Code of Conduct on the Safety and Security of Radioactive Sources with its supplementary Guidance on the Import and Export of Radioactive Sources.

Except as mentioned above the Danish legislation for radioactive waste and spent fuel management are unchanged. A list of relevant Acts, Orders etc. in force by 1 October 2008 is given in Annex 1.

*Article 20. Regulatory body*

No new development. Please refer to the second National Report, 2005[4].

## Section F. Other General Safety Provisions

*Article 21. Responsibility of the licence holder*

No new development. Please refer to the second National Report, 2005[4].

*Article 22. Human and financial resources*

The responsibility for operation and decommissioning of the nuclear facilities, as well as continued waste management at the Waste Management Plant was transferred to Danish Decommissioning from the Risø National Laboratory in 2003. The staff assigned to the decommissioning process and for operating the Waste Management Plant was reassigned to Danish Decommissioning assuring qualified and adequate human resources needed for safety related activities during the decommissioning and the operating lifetime of the Waste Management Plant.

The Operational Limits and Conditions for Danish Decommissioning states that every employee at any level in the organisation shall maintain adequate training and instruction necessary to comply with the requirements of the position, in full accordance with the safety provisions prescribed by the Nuclear Regulatory Authorities. As Danish Decommissioning is subject to minor but continuous staff adjustments and replacements, training courses, seminars, and more extensive classes are therefore undertaken in order to ensure both an adequate level of qualification as well as transfer of relevant experience from skilled members of the staff.

For Danish Decommissioning the availability of adequate financial resources is also assured, inasmuch as the organization is subordinated the Danish Ministry of Science, Technology and Innovation. Thus the financial provisions to support the safety of facilities for radioactive waste management are in place.

Continuously available, adequate and qualified human resources were also one of the challenges noted in the Rapporteur's Report with respect to the Nuclear Regulatory Authorities. As Denmark is a non-nuclear country with little or no focus on maintaining adequate training courses etc. in ionizing radiation and radiation protection, adequate and qualified human resources have been made available by internal courses and seminars throughout the period since the Second Review Meeting.

Facing two replacements in the near future the Nuclear Regulatory Authorities again have to cope with the lack of adequate training courses as well as the persistent demand for highly educated people in all parts of the Danish labour market.

With respect to new employees, the Nuclear Regulatory Authorities most likely have to continue to allocate in-house resources in order to ensure adequate training and education in radiation protection and waste management, eventually in collaboration with sister organisations in other Nordic countries and abroad.

[4] National Report from Denmark, 2005:
http://www.sst.dk/publ/Publ2005/SIS/Joint_Convention/Joint_Convention_Report_2005.pdf

*Article 23. Quality assurance*

An important precondition for obtaining the Nuclear Regulatory Authorities final approval for decommissioning was that Danish Decommissioning attained quality certification in accordance with the ISO 9001 standard. Danish Decommissioning was certified in June 2004. Since then the quality assurance system for the entire process of decommissioning, including all radioactive waste management, has been based on the DS/EN ISO 9001. The system is inspected biannually by Danish Standards (DS) and every third year a complete audit of all certified functions is conducted. This was last carried out in 2007 and it confirmed the validity of the certification. All audit reports are available to the regulatory authorities.

In addition, specially trained personnel at Danish Decommissioning regularly conduct internal audits as required by the standard. With respect to the functions delivered by the Radiation Research department at the Risø National Laboratory for Sustainable Energy, Danish Decommissioning carries out second-party audits in order to determine the appropriateness and effectiveness of contracting laboratories. These audit reports are also available to the regulatory authorities.

In 2005 the Nuclear Regulatory Authorities also required an independent accreditation of the clearance laboratory (F-lab) in order to assure compliance with International Standards. In order to facilitate accreditation of the relevant functions, F-lab was initially allowed to operate under a limited approval, specifying in detail the material which could be subject to clearance measurements prior to a formal independent accreditation.

In May 2007 F-lab was accredited by the Danish Accreditation and Metrology Fund (DANAK) according to the ISO 17025 standard on general requirements for the competence of testing and calibration laboratories. The accreditation (DANAK No. 488) is specified for the: Measurement of radioactivity and content of radionuclides as well as determination of clearance index for solid items and waste with respect to clearance. F-lab is now subject to routine inspections by DANAK.

In 2006, Danish Decommissioning established a computerized Waste Documentation System with bar code identification, in order to ensure proper documentation of inventory as well as real time documentation of spatial location of any characterised waste item. This, as well as the use of colour-coded containers, is anticipated to minimize the risk of waste handling and waste destination errors and have been taken into operation within the reporting period.

Finally, in accordance with the quality assurance system various parts of the waste handling equipment, especially at the Waste Management Plant, have been refurbished in order to ensure a continuous safe and adequate waste handling.

*Article 24. Operational radiation protection*

In accordance with the Nuclear Installations Act (1962) Danish Decommissioning is subject to Operational Limits and Conditions, which set out regulations covering all aspects of decommissioning, including administrative structure, project planning and management, detailed operation planning, quality assurance, characterization of radioisotope inventory, operational radiation protection, safety assessment, environmental impact assessment and documentation.

The general principles for operational radiation protection in relation to decommissioning are similar to those applied during operation of the facilities. The operational radiation protection program must comply with the regulations given in Operational Limits and Conditions for Danish Decommissioning. Accordingly, the mandatory radiation surveillance programs cover all relevant decommissioning operations, and the received doses are reported to the Nuclear Regulatory Authorities in normal as well as abnormal situations.

With respect to personnel at contractor level, it is the responsibility of Danish Decommissioning to ensure that all relevant personnel are instructed to the necessary level, in order to accomplish the assignments properly in terms of health physics and radiological safety. Contractor level instructions are typically on the order of three hours in total.

**Discharge**

Releases of radioactive materials from the Waste Management Plant are primarily liquid and derive from the radioactive wastewater distillation plant which conducts the distillate to the inactive waste water system which again is led into Roskilde Fjord.

Since the reactors were taken out of operation, the release of tritium to Roskilde Fjord has been reduced by one order of magnitude and is now around $10^3$ GBq/y as shown in figure 5. The minor increase from 2003 to 2004 is due to cleanup in connection with operation of the distillation column. The relatively high discharges in 2006 and 2007 were caused by an erroneous washing process in late 2006 leading to the small discharges to Roskilde Fjord in late 2006 and early 2007. The procedure described in the quality management system has been adjusted to avoid recurrence.

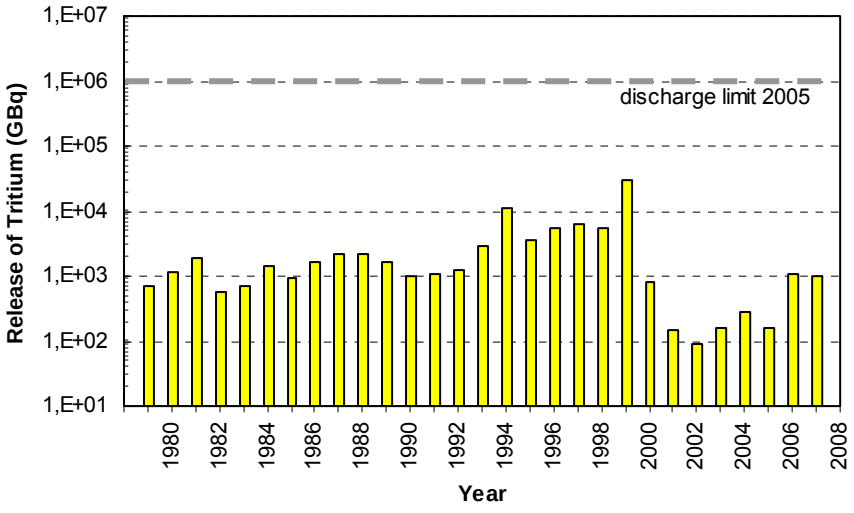


*Figure 5. Annual release of tritium into Roskilde Fjord from the Waste Management Plant.*

The annual release of dissolved gross β/γ-activity has generally been decreasing since the reactors were taken out of operation and is now less than 0.1 GBq of which most is the naturally occurring $K^{40}$. The annual releases are shown in figure 6.

*Article 25. Emergency preparedness*

No new development. However, a thorough revision of the Nation-wide nuclear preparedness plan will be implemented in the period 2008-2009 under the responsibility of the Nuclear Division of Danish Emergency Management Agency. Sector based responsibility is fundamental for the Danish emergency preparedness and, wherever possible, the Danish nuclear emergency system is based on organisations and preparedness arrangements already in force for other purposes.

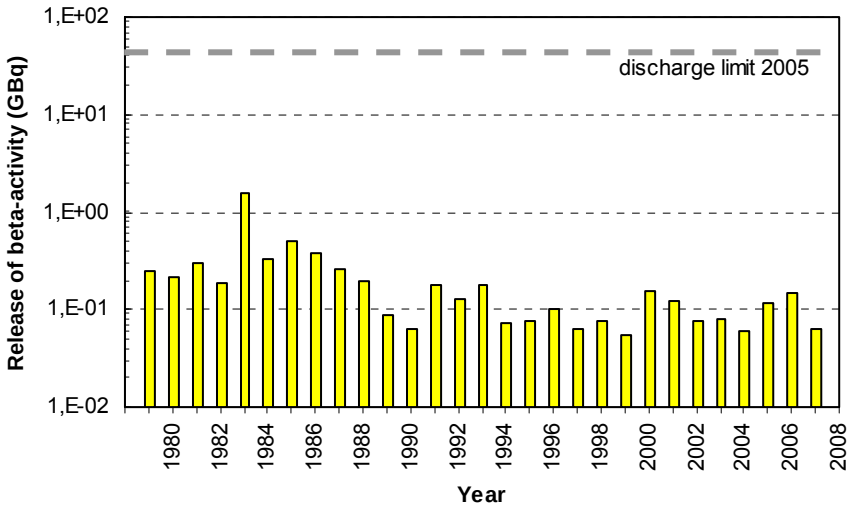


*Figure 6. Annual release of gross ß/γ-activity into Roskilde Fjord from the Waste Management Plant.*

*Article 26. Decommissioning*

**Doses from the decommissioning of DR 1**
The decommissioning of DR 1 was finalised in late 2005 shortly after the submission of the previous National Report from Denmark. A final account of doses from the decommissioning of DR 1 therefore had to await the present publication to be reported.

With respect to DR 1 decommissioning, all DD personnel working in radiation fields wore TL dosimeters as well as digital dosimeters. In addition, the technicians performing dismantling work in particularly hot areas wore special dosimeters at fingers, around the wrists and at the front of the head, as appropriate. The total collective dose as measured by the digital dose meters was slightly above 1 man mSv and the highest individual dose was 0.3 mSv. The readings from finger dosimeters were 850 µSv and 350 µSv for the two technicians who performed dismantling work in particularly hot areas.

All staff from the contractors who carried out the concrete demolition wore TL dose meters and delivered urine samples before the demolition work started and after its completion. No doses were recorded and there were no signs of intake of radionuclides during the work.

**Doses from the decommissioning of DR 2**
Decommissioning of DR 2 was finalised during spring 2008. A final account of doses and surveillance techniques from this undertaking will be reported in the final decommissioning report for DR 2, which is still pending. However, preliminary data reveals that the total collective dose for 2006, including internal and external staff, will be less than 6 man mSv. Staff from Danish Decommissioning had a collective dose of 1.6 mSv and staff from the contractors who carried out the demolition of concrete had a collective dose of 4.1 mSv. The maximum individual doses for internal and external staff were 0.6 and 1.0 mSv, respectively.

**Doses from the decommissioning of DR 3**
Radiological characterisation is fundamental to the planning of waste handling. Characterisation of major parts of reactor DR 3, such as the primary reactor components and the primary cooling system, were done during 2005. During this process the collective dose was 2.6 mSv and the highest individual dose was 0.7 mSv. Characterisation of all DR 3 fuel storage units and associated equipment took place in 2006 and 2007, and gave rise to a collective dose of 5.8 mSv and an individual maximum dose of 0.7 mSv.

## Section G. Safety of Spent Fuel Management

*Article 4. General safety requirements*
*Article 5. Existing facilities*
*Article 6. Siting of proposed facilities*
*Article 7. Design and construction of facilities*
*Article 8. Assessment of safety of facilities*
*Article 9. Operation of facilities*
*Article 10. Disposal of spent fuel*

As a consequence of the decision taken by the Danish Parliament in 1985, there are, at present, no considerations or plans for taking any kind of nuclear reactors into operation in Denmark. Thus, there are no plans for siting, designing, construction or operation of spent fuel facilities or disposal of spent fuel. Spent fuel from the research reactors DR 2 and DR 3 has been transferred to USA's jurisdiction according to an agreement with the US Department of Energy.

The only exemption from this is the minimal amount of spent fuel from the research reactor DR 1 and about 233 kg experimentally produced and irradiated spent fuel of power reactor type remaining from post-irradiation investigations in the former Hot Cells. This minimal amount of spent fuel is stored under safe and secure conditions awaiting a decision on the final management. The storage does not give rise to any discharges of radioactive materials to the environment and hence no exposure of the public.

Finding a solution for the minimal amount of spent fuel was mentioned as a challenge in the 2006 Rapporteur's report for Denmark. Since the Second Review Meeting Denmark has been searching extensively for an international solution regarding the spent fuel in question, but until now this effort has been unsuccessful. If an international solution cannot be found, the option for Denmark will be to dispose this spent fuel in the coming Danish repository for low and intermediate level waste. The minimal amount of spent fuel is therefore part of the overall waste volume, which is taken into account in the planning for establishing a final repository for Danish low and intermediate level waste; see section H for further details.

## Section H. Safety of Radioactive Waste Management

*Article 11. General safety requirements*
*Article 12. Existing facilities and past practices*
*Article 13. Siting of proposed facilities*
*Article 14. Design and construction of facilities*
*Article 15. Assessment of safety of facilities*

The inspection of waste storage facilities by the Nuclear Regulatory Authorities was also mentioned as a challenge in the 2006 Rapporteur's Report. Inspections at each facility are routinely carried out by the authorities with 6 to 12 month intervals.

Furthermore, the quantity of internal audits that the operator has to report to the authorities has been increased. The improved internal audits sustain the safety; not only due to the inspections themselves, but also due to the improved focus on the waste management system in general.

**Establishing a final repository for low and intermediate level waste**
Establishing a final repository was highlighted as one of challenges for Denmark in the 2006 Rapporteur's Report. In the following is an account of the progress and status of the project.

The Danish Parliament has in March 2003 agreed to initiate the process of preparing a 'Basis for Decision' regarding a Danish disposal facility for LILW. The purpose of the 'Basis for De-

cision' is to describe the background, requirements and scope of the project to the decision makers and stakeholders.

**The 'Basis for Decision'**
The 'Basis for Decision' has been finalised by a cross-ministerial Working Group and has been forwarded to the government. The Working Group consists of relevant members from various departments, agencies and operators under the Ministry of Health and Prevention, Ministry of the Environment, Ministry of Climate and Energy as well as the Ministry of Defence.

It is expected that the Parliament in the fall of 2008, after the deadline of this report, will discuss the 'Basis for Decision' and eventually agree to proceed with the project as described in the 'Basis for Decision'.

The 'Basis for Decision' describes the background for the project, the legal aspects, foreign experiences and the amount and type of waste to be deposited. It also suggests various design solutions and describes a way forward for the siting process and how to involve stakeholders. In the following the content of the 'Basis for Decision' will be described in more details.

**Legal aspects**
The national and international legal aspects relevant for a repository are presented in the 'Basis for Decision'. It is concluded by the Working Group that the national regulation is adequate for establishing a final repository. However, it should be considered to establish a specific legal system for the repository.

With regard to international legal recommendations and obligations it is the explicit Danish policy to be committed to these.

**Waste types and waste amounts**
The Danish radioactive waste is of different origin, type and activity. It arises partly from the former nuclear research and partly from other Danish users of radioactive materials e.g. the health, industry and research sectors. Danish Decommissioning has estimated the type and amounts of waste to be deposited in a Danish repository. In table 6 the data, as presented in the 'Basis for Decision', is shown.

*Table 6. Estimated amounts (rounded) of waste to be deposited in a Danish repository, updated 2008.*

| Waste type | Volume ($m^3$) |
|---|---|
| Waste from decommissioning | 2,100 |
| Low activity waste (existing) | 2,000 |
| Intermediate activity waste (existing) | 540 |
| Special waste | 180 |
| Tailings and contaminated concrete | 1,100 |

As the decommissioning is ongoing, the final amount of decommissioning waste is not known. The presented figure is thus a rough estimate, whereas the figures for low activity waste and intermediate activity waste are exact amounts. The special waste can be separated into the following types: 233 kg of experimentally irradiated uranium, 4.9 kg 19.9 % HEU in a 15 l solution equivalent to approximately 975 g U-235 in total, ~20 pcs. of larger alpha-sources, 5 kg of uranium in solution, which is solidified in concrete, 100 l of heavy water and 2,000 kg of non-irradiated uranium. The tailings and contaminated concrete are legacy from uranium extraction research carried out in the 1970's and 80's.

At the moment the activity of the waste in table 6 is about 1.400 TBq whereof the special waste constitutes approx. 800 TBq. In figure 7, the activities of the various waste categories are presented.

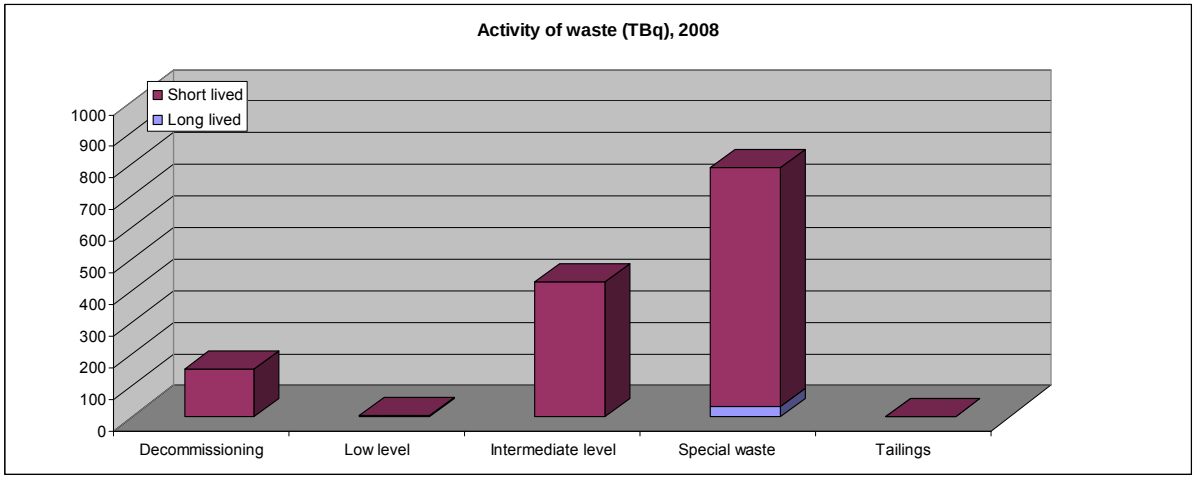


*Figure 7. Activity of the various waste types in 2008.*

**General principles for the protection of humans and the environment**
An important step in the preparation of the "Basis for Decision" has been to develop the 'Fundamental principles for safety and environmental protection'. These fundamental principles shall describe the framework with which all the work related to the repository shall comply. It is the Danish policy to follow the recommendations and standards from IAEA, ICRP and other relevant international organisations. Furthermore, Denmark has ratified the IAEA Joint Convention, and is obliged to act within its framework.

Based on the recommendations by IRCP and the IAEA safety standards, Denmark has established 4 principles that shall apply for all work related to the establishing of a repository for LILW. The 4 principles are the following:

***1. Protection of humans and the environment***
*Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for humans and the environment.*

Any exposure of humans much be kept as low as reasonably achievable taking into consideration economical and societal factors. Radiation can harm all living creatures, not just humans. Radiation protection includes therefore also plants, animals and the environment in general. A final repository must be designed as to ensure that it is not a risk to the biological diversity.

***2. Protection beyond national borders***
*Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.*

It is based on the premise that a country has a duty to act responsibly and, as a minimum, not to impose effects on human health and the environment in other countries more detrimental than those which have been judged acceptable within its own borders.

***3. Protection of future generations***
*Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable*

*today. Likewise, radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.*

Consideration for future generations is of fundamental importance in the management of radioactive waste. This principle is derived from an ethical concern for the health and environment of future generations, as well as a principle that the generations that receive the benefits of a practice should bear the responsibility to manage the resulting waste.

***4. The legal framework***

*Radioactive waste shall be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions.*

The responsibilities of each party or organization involved should be clearly allocated for all radioactive waste management activities that take place in a country. Separation of the regulatory function from the operating function is required to guarantee independent review and overseeing of radioactive waste management activities.

**Safety criteria and safety analyses**

The general principles described above have been transformed into actual quantitative criteria for the protection of humans. During the lifetime of a repository various requirements for radiation protection for workers and individuals in the population are determined based on the ICRP principles of justification, optimisation and dose limitation.

During the operational period, the requirements shall be similar to the existing dose limits and dose constraints in the present Danish legislation: worker dose limit of 20 mSv/y and dose limits of 1 mSv/y and reference dose (dose constraint) for nuclear installation of 0.1 mSv/y for individual members of the population. After closure, the general dose constraint shall be 0.01 mSv/Y with regard to the expected development of the repository. This is equal to the clearance criteria in the Danish legislation and acknowledges the principle that future generations should be protected at the same level as the present generation. The dose constraint is equal to that applicable for material released from regulatory control and hence not considered radioactive.

Additionally, there is a dose constraint for potential isolated incidents, such a minor earthquakes and intrusion, of 1 mSv per year. The recommended safety criteria for the repository are presented in table 7. An incident, that is very unlikely or where the consequences are so destructive that dispersal of LILW is a minor problem, is not included (e.g. meteor, major earthquake).

*Table 7. Recommended safety criteria (dose constraints) for individual members of the public.*

| Period | Scenario | Reference dose, mSv per year |
|---|---|---|
| Operational period | Normal operation | 0.1 |
| After closure | Expected development | 0.01 |
| | Potential incidents | 1 |

The early safety analysis and safety case will be of a more conceptual type using general data that are available. As the process evolves and more site specific knowledge is gathered, the safety analysis and safety case will become more and more detailed. During the process there will be a close integration between the safety analysis and the design of the engineered barriers.

**Concepts for final repository**

Because there is no HLW to be placed in the repository, a deep geological repository is considered irrelevant. As most of the Danish waste is short-lived LILW it is obvious to consider a near-surface repository in line with IAEA recommendations. However, the Safety Analyses may show that the small amount of long-lived LILW is unsuitable for a near-surface repository. To ensure the accommodation of the long-lived waste it is therefore necessary to look into the concept of an intermediate level depth repository as well. Three conceptual designs have been suggested for the LILW repository (Figure 8):

Option 1: A near surface repository (<30 meters under terrain). (For option 1, three different positions relative to surface and water table are given in the figure).
Option 2: A near surface repository (<30 m u.t.) in combination with a deeper borehole (30-300 m u.t.).
Option 3: An intermediate deep repository (30-100 m u.t.).

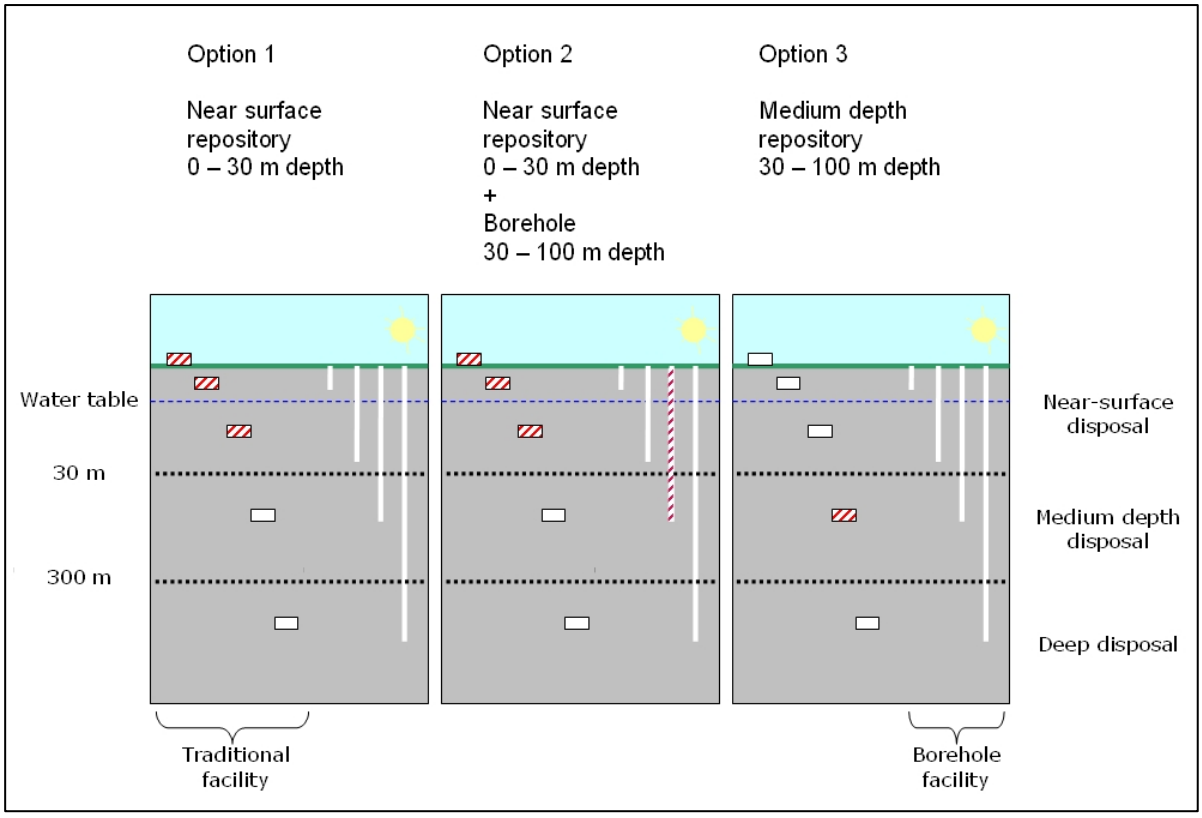


*Figure 8. The three conceptual designs for a LILW repository. Options 1 and 2 show three possible positions relative to surface and water table. Only hatched symbols show the possible positions within an "option".*

The type of repository primarily depends on the safety analysis, geology and costs.

At the present time there has not been a decision regarding reversibility. This issue has been brought up by stakeholders as an important parameter. Hence, the working group has recommended that in the continued process, the question of reversibility is an option to be considered. The decision whether the repository shall be reversible or not will be made later, when more knowledge of the implications with regard to safety, design and cost are available.

**The process related to establishing the repository**
In the Parliamentary decision from 2003 it was stated, that it is of utmost importance to make the process open and transparent. Hence, stakeholder involvement and information is a major issue in the process. Until now two hearings regarding the 'Basis for Decision' have been held and a leaflet describing the project has been produced. The leaflet has been sent out to all municipalities as well as relevant organisations.

One major aspect of establishing a repository is to decide on the process for siting. As a starting point, all of Denmark is considered relevant. In a stepwise progression the siting process reduces the number of potential localities until one is finally selected. A short description of the process as proposed in the 'Basis for Decision' is given in the following.

The first step in the process is to consist of three parallel desk studies: 1) One study that looks at the Danish geology, 2) one study that looks at the safety and cost of the three conceptual designs, and 3) one study that looks at the risk of transporting the waste to a repository.

Based on these three desk studies approximately 20 areas are expected to be pointed out as a possible location for a future repository. At this time the public will have the opportunity to bring forward ideas for the disposal project as well as for the topics of the Environmental Impact Assessment (EIA).

For each of the 20 sites more detailed Vicinity Studies and EIA's will be carried out. The Vicinity Studies will look upon how a repository will/can affect the vicinity with regard to e.g. societal and spatial planning issues. It is expected that these Vicinity Studies and the EIA's will reduce the amount of relevant localities to 5-10.

At this time all relevant material (studies, reports etc) as well as a public hearing will constitute the basis for The Planning Act in Denmark[5], according to which relevant localities can be retained for repository investigations by the government.

The actual decision to start field investigations will be taken by the Parliament. It is expected that 2-3 sites will be included in the investigation programme. Based on thorough investigations and stakeholder involvement one site will be selected and the decision to establish a repository will be implemented through a specific act decided by Parliament.

*Article 16. Operation of facilities*
No new development in the general operation of the facilities. However, there has been the following development with regard to the handling and storage of waste:

- A new type of steel lined concrete container has been developed in order to improve the management of the decommissioning waste. The steel liner and the concrete container are produced separately in such a way that the steel liner fits into the concrete container. The use of this steel container has been approved for interim storage by the regulatory authorities in early 2006.
- Control with ISO-containers. The control with ISO-containers used for interim storage of decommissioning waste and other potential radioactive waste has been improved. The physical location of these has been restricted to specific areas, and the maximum dose rates on the outside of the ISO-containers have been included in the quarterly reports on health physics.
- A decontamination cabinet equipped with high pressure water cleaners and glass blasting tools has been established in the DR 3 building complex.

[5] Ministerial order with the purpose of allocating certain areas as potential repository sites

*Article 17. Institutional measures after closure*

No new development. Please refer to the second National Report, 2005[6].

## Section I. Transboundary movement

*Article 27. Transboundary movement*

No new developments regarding the existing practice and legal system and requirements for transboundary movement of radioactive waste. However, the European Council has adopted Directive 2006/117/EURATOM of 20 November 2006 on the supervision and control of shipments of radioactive waste and spent fuel. Denmark expects to implement this directive in a new Order later this year coming into force 25 December 2008 and replacing Order no. 969 of 13 December 1993 on international transfer of radioactive waste. The new directive and the Order will, in addition to shipments of radioactive waste, also cover all shipments of spent fuel, whether it is intended for disposal or for reprocessing.

The National Institute of Radiation Protection has in the period from the last Review Meeting authorized 11 transboundary movements between EU-countries, but only with Denmark as a country of transit.

## Section J. Disused sealed Sources

*Article 28. Disused sealed sources*

Order no. 985 of 11 July 2007 on sealed radioactive sources in addition to Order no. 154 of 6. March 1990 on smoke detectors and consumer products containing radioactive materials implement all obligations under Article 28 of the Convention, ensuring that the possession and storage of disused sealed sources take place in a safe manner.

The conditions for re-entry for storage of disused sealed sources originally produced in Denmark are unchanged and will on application be considered case by case.

The survey for orphan sources was mentioned as one of the challenges in the 2006 Rapporteur's Report and action has been taken as described below.

Disused orphan radioactive sources are regularly found in metal scrap. Fortunately until now only sources with low activity and only a handful each year have been found in Denmark. Knowing that these sources can lead to unwanted doses to persons the National Institute of Radiation Protection decided to conduct a preventive survey in selected scrap yards. The survey was conducted in cooperation with the Nuclear Division, Danish Emergency Management Agency. The total survey included seven scrap yards and the survey was completed in October 2006. A mobile measurement system (car borne) equipped with a 4L NaI(Tl) and a GR-320 spectrometer was used for the survey. No radioactive material was found in any of the scrap yards that were examined.

[6] National Report from Denmark, 2005:
http://www.sst.dk/publ/Publ2005/SIS/Joint_Convention/Joint_Convention_Report_2005.pdf


*Figure 9. Mobile measurement system equipped with a 4L NaI(Tl) and a GR-320 spectrometer.*

## Section K. Planned Activities to Improve Safety

**International co-operation**

Below are examples of what has been done in the past to improve safety through international co-operation. This participation in international co-operation is planned to continue in the future and is as such part of the planned activities to improve safety.

International co-operation is becoming more and more important both on the international scene for obvious reasons, but also on the national scene as one of several means to react to the challenge of the diminishing competences and knowledge in several relevant fields for the safety of spent fuel and radioactive waste management. Being a small country without a nuclear power programme this is even more important for Denmark. As a consequence Denmark participates with its limited resources in many international groups in order to follow, understand and take part in the evolution of the safety of nuclear fuel and radioactive waste management. The international co-operation is essential for both the Nuclear Regulatory Authorities and the operators of nuclear installations and both have taken actively part in this for many years.

In the IAEA context, Denmark has for the last five years taken actively part in the development of the IAEA Safety Standards with representation in both the Commission on Safety Standards (CSS) and three Committees (RASSC, WASSC, TRANSSC). Denmark has also offered officers for IAEA Reviews and Appraisals in other Member States (Team leader for the Integrated Regulatory Review Service (IRRS) mission to Australia in 2007). Finally both the operator and regulator from Denmark have taken part in the international project on the Evaluation and Demonstration of Safety during Decommissioning of Nuclear Facilities (DeSa) with the finalised Danish decommissioning project of the Danish research reactor DR 1 being one of the test cases selected for the second phase of the DeSa Project.

In the Euratom context, Denmark has for many years been actively engaged in EU working groups preparing EU legislation or given advice on the implementation of EU legislation in EU Member States, especially within the Euratom Article 31 Group of Experts. From 2007 the two Danish Nuclear Regulatory Authorities are represented in the newly created European High Level Group on Nuclear Safety and Waste Management (HLG) with the aim of maintaining and further improving the safety of nuclear installations and the safety of the management of spent fuel and radioactive waste.

Co-operation between the Nordic countries has been on-going for many decades, and has been focusing on the development of common Nordic principles and strategies, as well as

day-to-day operationally collaboration between the authorities. An example of this is the very close harmonisation in nuclear and radiological emergency planning and preparedness.

To seek continuous improvement in the Danish arrangements for the nuclear and radioactive waste safety, the Danish Nuclear Regulatory Authorities have jointly decided to set up a plan to undertake a self assessment, based on all or parts of the elements in the self assessment methodology used in the preparation of an IAEA International Regulatory Review Service (IRRS) mission. Such a self assessment will also constitute a part of the follow-up on the adopted working programme for the European High Level Group on Nuclear Safety and Waste Management.

# Annex A. Danish Legislation – Spent Fuel and Radioactive Waste

The Danish legislation listed below is in force per 1 October 2008. The legislation is available in Danish at the web site of the National Institute of Radiation Protection[7].

**Acts:**

- Act No. 94 of 31 March 1953 on use etc. of radioactive materials.
- Act No. 170 of 16 May 1962 on nuclear installations.

**Ministerial Orders:**

- Ministry of the Interior (now Ministry of Defence) Order No. 278 of 27 June 1963 on protective measures against accidents in nuclear installations (atomic installations) etc. with amendments in Order No. 502 of 1 October 1974.
- Ministry of the Environment (now Ministry of Health and Prevention) Order No. 574 of 20 November 1975 on precautionary measures for the use etc. radioactive substances.
- Ministry of the Interior and Health (now Ministry of Health and Prevention) Order No. 192 of 2 April 2002 on exemptions from Act on the use of radioactive substances.

**Operational Limits and Conditions issued by the Nuclear Regulatory Authorities** (The Nuclear Division under the Danish Emergency Management Agency and the National Institute of Radiation Protection under the National Board of Health)**:**

- Operational Limits and Conditions for Danish Decommissioning.
- Operational Limits and Conditions for Risø National Laboratory.

**Orders from the National Board of Health (National Institute of Radiation Protection):**

- National Board of Health Order No. 154 of 6 March 1990 on smoke detectors and consumer products containing radioactive materials with amendments in Orders No. 547 of 23 July 1993 and No. 793 of 19 October 1999.
- National Board of Health Order No. 546 of 23 June 1993 on transfer of radioactive materials.
- National Board of Health Order No. 969 of 13 December 1993 on international transfer of radioactive waste.
- National Board of Health Order No. 663 of 12 July 1994 on outside workers, who are exposed to ionizing radiation in a CE-country with amendments in Order no. 824 of 31 October 1997.
- National Board of Health Order No. 823 of 31 October 1997 on dose limits for ionizing radiation.
- National Board of Health Order No. 954 of 23 October 2000 on the use of unsealed radioactive sources in hospitals, laboratories etc.
- National Board of Health Order No. 993 of 5 December 2001 on transport of radioactive materials.
- National Board of Health Order No. 985 of 11 July 2007 on sealed radioactive sources.

[7] http://www.sis.dk