Nordisk kernesikkerhedsforskning
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Pohjoismainen ydinturvallisuustutkimus
Nordisk kjernesikkerhetsforskning
Nordisk kärnsäkerhetsforskning
Nordic nuclear safety research

NKS-62
ISBN 87-7893-117-7

Safety and Radiation Protection in Waste Management

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Studsvik RadWaste AB, Sweden

December 2001

Nordic Nuclear Safety Research (NKS)

organizes joint four-year research programs involving some 300 Nordic scientists and dozens of central authorities, nuclear facilities and other concerned organizations in five countries. The aim is to produce practical, easy-to-use reference material for decision makers and help achieve a better popular understanding of nuclear issues.

To that end the results of the sixth four-year NKS program (1998 - 2001) are herewith presented in a series of final reports comprising reactor safety, radioactive waste management, emergency preparedness, radioecology, and databases on nuclear threats in Nordic surroundings. Each report summarizes the main work, findings and conclusions of the six projects carried out during that period. The administrative support and coordination work is presented in a separate report. A special Summary Report, with a brief résumé of all projects, is also published. Additional copies of the reports on the individual projects as well as the administrative work and the Summary Report can be ordered free of charge from the NKS Secretariat.

The final reports - together with technical reports and other material from the 1998 - 2001 period - will be collected on a CD-ROM, also available free of charge from the NKS Secretariat.

During the last few years a growing interest has been noted among sister organizations in the three Baltic States, especially in the field of emergency preparedness, radiation protection and radioecology. This has widened the scope of our joint Nordic work and fed new influences and valuable competence into the NKS program. The Baltic participation is therefore gratefully acknowledged.

NKS-62
ISBN 87-7893-117-7

klæbel's offset tryk a-s, 2002

The report can be obtained from
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DK – 4000 Roskilde
Denmark

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www.nks.org
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NKS-62
ISBN 87-7893-117-7

Safety and Radiation Protection in Waste Management

Final Report of the
Nordic Nuclear Safety Research
Project SOS-3

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December 2001

This is NKS

NKS (Nordic Nuclear Safety Research) is a scientific cooperation program in nuclear safety, radiation protection and emergency preparedness. It is a virtual organization, serving as an umbrella for joint Nordic initiatives and interests. Its purpose is to carry out cost-effective Nordic projects producing seminars, exercises, reports, manuals, recommendations, and other types of reference material. This material, often in electronic form on the official homepage www.nks.org or CD-ROMs, is to serve decision-makers and other concerned staff members at authorities, research establishments and enterprises in the nuclear field.

A total of six projects were carried out during the sixth four-year NKS program 1998 - 2001, covering reactor safety, radioactive waste, emergency preparedness, and radioecology. This included an interdisciplinary study on nuclear threats in Nordic surroundings. Only projects of particular interest to end-users and financing organizations have been considered, and the results are intended to be practical, useful and directly applicable. The main financing organizations are:

- The Danish Emergency Management Agency
- The Finnish Ministry for Trade and Industry
- The Icelandic Radiation Protection Institute
- The Norwegian Radiation Protection Authority
- The Swedish Nuclear Power Inspectorate and the Swedish Radiation Protection Authority

Additional financial support has been received from the following organizations:

In Finland: Fortum (formerly Imatran Voima, IVO); Teollisuuden Voima Oy (TVO)

In Sweden: Sydkraft AB; Vattenfall AB; Swedish Nuclear Fuel and Waste Management Co. (SKB); Nuclear Training and Safety Center (KSU)

To this should be added contributions in kind by all the organizations listed above and a large number of other dedicated organizations.

NKS expresses its sincere thanks to all financing and participating organizations, the project leaders, and all participants, all in all some 300 persons in five Nordic countries and the Baltic States, without which the NKS program and this report would not have been possible.

Disclaimer

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In particular, neither NKS nor any other organization or body supporting NKS activities can be held responsible for the material presented in this report.

Abstract

During 1998-2001, a project on the management of radioactive waste was carried out as part of the NKS programme. The project was called NKS/SOS-3 and was divided into three subprojects:

- SOS-3.1: Environmental Impact Assessment (EIA)
- SOS-3.2: Intermediate storage
- SOS-3.3: Contamination levels in metals

SOS-3.1 included four EIA seminars on the use of EIA in the Nordic countries. The seminars were held in Norway in 1998, Denmark in 1999, Iceland in 2000 and Finland in 2001. (The last seminar was performed in co-operation with the NKS project SOS-1.) The seminars focused on experiences from EIA procedures for the disposal of radioactive waste, and other experiences from EIA processes.

SOS-3.2 included a study on intermediate storage of radioactive waste packages in the Nordic countries. An overview of experiences was compiled and recommendations were made regarding different intermediate storage options, as well as control and supervision.

SOS-3.3 included investigation of contamination levels in steel, aluminium and magnesium samples from smelting facilities, and an overview of current practice for clearance in the Nordic countries.

Key words

Clearance, clearance levels, naturally occurring radioactive materials, radioactive waste, radioactive material, intermediate storage, waste disposal, environmental impact assessment, environmental impact statement, gamma spectrometric measurements, beta measurements, neutron activation analyses.

Summary

General

During 1998-2001, a project on the management of radioactive waste was carried out as part of the NKS programme. The project was called NKS/SOS-3 and was divided into three subprojects: SOS-3.1, SOS-3.2 and SOS-3.3. The first of these, SOS-3.1, dealt with Environmental Impact Assessment (EIA), SOS 3.2 dealt with intermediate storage, and SOS-3.3 dealt with contamination levels in metals. Each of these subprojects related to earlier NKS work on the management and disposal of radioactive waste. SOS-3.1 was a continuation of a subproject on EIA (AFA-1.3) in the previous programme period of 1994-1997. SOS-3.2 was a continuation of two other subprojects in the same programme period: AFA-1.1 on waste categorisation and AFA-1.2 on performance analysis. SOS-3.3 was a continuation of earlier NKS work on clearance from regulatory control (KAN-1.1, 1994).

Representatives from Denmark, Finland, Norway and Sweden participated in all three subprojects, while representatives from Iceland participated in SOS-3.1 and SOS-3-3. Most of the SOS-3 work has been performed in a broad group of experts. This has contributed to a better understanding of the waste situation in the different countries and has also made it possible to learn from each other. Furthermore, it has in some cases contributed to common recommendations.

Priority was given to a Nordic perspective. Therefore, the work was focused less on waste from nuclear power plants than on waste from research, hospitals and industry.

The target group for the results is primarily authorities and organisations managing waste in the Nordic countries. However, the results are presumably useful in other countries as well. This applies particularly to the results from SOS-3.3, since the knowledge within this field is very limited in the world.

Environmental Impact Assessment (SOS-3.1)

The management and disposal of radioactive waste is governed by national legal frameworks and international requirements and guidance on EIA. The SOS-3.1 subproject included four EIA seminars on the use of EIA in the Nordic countries. The seminars were held in Norway in 1998, Denmark in 1999, Iceland in 2000 and Finland in 2001. The last seminar was performed in co-operation with the NKS project SOS-1.

The seminars focused on experiences from EIA procedures for the disposal of radioactive waste and other experiences from EIA processes. Both Finland and Sweden have repositories for operational waste from nuclear power plants. Finland has experiences from a performed EIA process regarding an encapsulation and disposal facility for spent nuclear fuel and similar EIA processor related to the modernisation of the existing nuclear power plants and a possible new plant. Sweden has experiences from an on-going EIA process regarding plans for disposal of spent nuclear fuel. Norway has experiences from a completed site with the construction of a combined disposal and storage facility for radioactive waste in Himdalen (KLDRA). Norway has also experience on EIA based on support of environmental clean-up activities in Russia. Denmark has, after closure of the research reactor DR3 in 1999, initiated comprehensive planning for the decommissioning of all the nuclear facilities at Risø. The initial steps in planning for a disposal facility have also been taken. Iceland has only small quantities of radioactive waste, but has experiences from EIA procedures related to other areas.

Intermediate storage (SOS-3.2)

Experiences of different intermediate storage conditions, and how these affect the containers and their content, are valuable both to authorities and industry when assessing and planning future storage facilities. The objective of SOS-3.2 was to analyse Nordic experiences of the storage of low- and intermediate-level waste, and to give recommendations on suitable intermediate storage conditions.

An overview of the principles for intermediate storage of radioactive waste packages in Denmark, Finland, Norway and Sweden was made. Recommendations were given regarding different intermediate storage options, as well as control and supervision. The disposal of drums at Kjeller in Norway was also included in the overview. This is an example of an intended disposal facility turned into what in practice has become a storage system.

Contamination levels in metals (SOS-3.3)

Clearance of radioactive material, in particular scrap metal, is a quite important issue, nationally as well internationally. The volume of scrap metal cleared for recycling is expected to increase as the nuclear installations grow older and the need for refurbishment and modernisation increases. However, controlled clearance is not the only source of radionuclides in materials and products. Other sources are naturally occurring radionuclides, accidental smelting of radiation sources, fall-out from nuclear weapon tests etc.

The SOS-3.3 subproject included both a study on clearance in the Nordic countries and a study on radioactivity in commercially available metals. Within the study on clearance in the Nordic countries, an overview of official requirements for clearance and information on clearance experiences was prepared. Practices from both nuclear and non-nuclear activities were presented.

Within the study on radioactivity in commercially available metals, samples from different steel, aluminium and magnesium producers in the Nordic countries were analysed at different laboratories. The samples were analysed with gamma spectrometric equipment. In some cases, beta measurements or neutron activation analyses were also performed. No activity at all or activities in the same range as the detection limits were found in the steel samples. Very low activities from natural uranium and thorium were found in some of the aluminium and magnesium samples. No indication of elevated radioactive contamination due to recycling of metals from the nuclear industry was found. However, it should be observed that it was only possible to analyse a limited number of samples in the SOS-3.3 study, since the measurements were very time-consuming.

The results from SOS-3.3 may be useful for comparison in the future, since changes may occur. It could then be of interest to compare the results from SOS-3.3 with results from new measurements.

Sammanfattning

Generellt

Under 1998-2001 genomfördes inom ramen för NKS (Nordisk kärnsäkerhetsforskning) ett projekt om avfall. Projektet kallades NKS/SOS-3. Det var uppdelat i tre delprojekt: SOS-3.1, SOS-3.2 och SOS-3.3. SOS-3.1 handlade om miljökonsekvensbeskrivningar (MKB), SOS-3.2 handlade om mellanlagring och SOS-3.3 handlade om kontaminationsnivåer i metaller. Vart och ett av delprojekten hade anknytning till tidigare NKS-arbete om hantering och slutförvaring av radioaktivt avfall. SOS-3.1 var en fortsättning på ett en delprojekt om MKB (AFA-1.3) från föregående programperiod 1994-1997. SOS-3.2 var en fortsättning av två andra delprojekt från samma programperiod; AFA-1.1 om avfallskategorisering och AFA-1.2 om funktionsanalys. SOS-3.3 var en fortsättning av tidigare NKS-arbete om friklassning (KAN-1.1, 1994).

Representanter från Danmark, Finland, Norge och Sverige deltog i alla tre delprojekten medan representanter från Island deltog i SOS-3.1 och SOS-3.3. Huvuddelen av arbetet har genomförts med ett brett deltagande. Detta har bidragit till bättre förståelse för avfallssituationen i de olika länderna och också gjort det möjligt att lära från varandra. Dessutom har arbetet i några fall bidragit till gemensamma rekommendationer.

Det nordiska perspektivet prioriterades. Därför fokuserades arbetet mindre på avfall från kärnkraftverk än på avfall från forskning, sjukhus och industri.

Målgruppen för resultaten är i första hand myndigheter och avfallshanterande organisationer i norden. Resultaten är dock antagligen av värde också i andra länder. Detta gäller framför allt resultaten från SOS-3.3 eftersom kunskapen i världen inom detta område är mycket begränsad.

Miljökonsekvensbeskrivningar (SOS-3.1)

Hantering och slutförvaring av radioaktivt avfall regleras genom nationell lagstiftning och internationella krav och rekommendationer om MKB. Delprojektet SOS-3.1 inkluderade fyra MKB-seminarier om användning av MKB i de nordiska länderna. Seminarierna hölls i Norge 1998, Danmark 1999, Island 2000 och Finland 2001. Det senaste seminariet genomfördes i samarbete med NKS-projektet SOS-1.

Seminarierna fokuserades på erfarenheter av MKB-processer för slutförvaring av radioaktivt avfall och om andra erfarenheter från MKB-processer. Både Finland och Sverige har slutförvar för driftavfall från kärnkraftverk. Finland har erfarenheter från en genomförd MKB-process beträffande inkapslings- och slutförvaringsanläggning för använt kärnbränsle och liknade MKB-processer knutna till modernisering av befintliga kärnkraftreaktorer och en ny eventuell kärnkraftreaktor. Sverige har erfarenheter från en pågående MKB-process beträffande slutförvaring av använt kärnbränsle. Norge har erfarenheter från uppförande av en anläggning för slutförvaring och mellanlagring av radioaktivt avfall i Himdalen (KLDRA). Norge har också MKB-erfarenheter baserade på stöd till miljöinsatser i Ryssland. Danmark har, efter 1999 då forskningsreaktorn DR3 stängdes, påbörjat omfattande planeringsinsatser inför rivning av alla de nukleära anläggningarna i Risø. De fösta stegen mot planering av ett slutförvar har också tagits. Island har bara små mängder radioaktivt avfall men har erfarenheter från MKB-processer med anknytning till andra områden.

Mellanlagring (SOS-3.2)

Erfarenheter av olika mellanlagringsförhållanden och hur de påverkar behållarna och innehållet är värdefullt både för myndigheter och industri vid bedömning och planering av framtida mellanlager. Syftet med SOS-3.2 var att analysera nordisk erfarenheter av mellanlagring av låg- och medelaktivt avfall och att ge rekommendationer om lämpliga förutsättningar för mellanlagring.

En sammanställning gjordes om principerna för mellanlagring av avfallskollin i Danmark, Finland, Norge och Sverige. Rekommendationer gavs beträffande val av mellanlagringsmetoder och också beträffande kontroll och övervakning. Markdeponering av fat i Kjeller inkluderades också i sammanställningen. Detta är ett exempel på en anläggning som från början var avsedd att vara en deponi men som senare i praktiken visade sig bli ett mellanlager.

Kontaminationsnivåer i metaller (SOS-3.3)

Friklassning av radioaktivt material, särskilt skrot, är en viktig fråga både nationellt och internationellt. Volymen skrot som friklassas för återanvändning förväntas öka när de nukleära anläggningarna blir äldre och behovet av renovering och modernisering ökar. Kontrollerad friklassning är emellertid inte den enda källan till radionuklider i material och produkter. Andra källor är naturligt förekommande radionuklider, strålkällor som av misstag kommer in till smältverk, nedfall från kärnvapentester etc.

SOS-3.3 delprojektet inkluderade både en studie om friklassning i de nordiska länderna och en studie om radioaktivitet i kommersiellt tillgängliga metaller. Inom studien om friklassing i de nordiska länderna gjordes en översikt av myndighetskrav på friklassing och erfarenheter av friklassning. Både tillämpningar från nukleära och icke-nukleära aktiviteter presenterades.

Inom studien om radioaktivitet i kommersiellt tillgängliga metaller analyserades prover från olika stål-, aluminium- och magnesiumproducenter i de nordiska länderna av olika laboratorier. Proverna analyserades med gammaspektrometriutrustning. I några fall genomfördes också betamätningar eller neutronaktiveringsanalyser. Ingen aktivitet alls eller aktiviteter i samma storleksordning som detektionsgränserna hittades i stålproverna. Mycket låga aktiviteter från naturligt uran och torium hittades i några av aluminium- och magnesiumproverna. Det finns inga indikationer på att återanvändning av metaller från den nukleära industrin gett upphov till förhöjd kontamination. Påpekas bör dock att det endast var möjligt att analysera ett begränsat antal prover i SOS-3.3-studien eftersom mätningarna var mycket tidskrävande.

Resultaten från SOS-3.3 kan vara användbara för jämförelser i framtiden eftersom förändringar kan äga rum. Det kan då vara av intresse att jämföra resultaten från SOS-3.3 med resultat från nya mätningar.

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1 Introduction

The research project SOS-3 on radioactive waste management consisted of three subprojects. Each of these related to earlier NKS work on the management and disposal of radioactive waste. The first subproject, SOS-3.1, dealt with the use of Environmental Impact Assessment (EIA) in the Nordic countries. The subproject was a continuation of the subproject on EIA (AFA-1.3) in the previous NKS programme period [1]. The objective of the SOS-3.1 subproject was to investigate differences and similarities between the Nordic countries' views on EIA. The work will contribute to the mutual understanding between the countries within the EIA area.

The second subproject, SOS-3.2, dealt with the intermediate storage of waste packages with low- and intermediate-level radioactive waste. The study was a continuation of the two subprojects AFA-1.1 and AFA-1.2 on waste categorisation and performance analysis [2-3]. The objective of the subprojects SOS-3.2 was to analyse Nordic experiences of storage of low- and intermediate-level waste, and to give recommendations on suitable storage conditions. The results can be used by authorities and industry in the assessment of existing and planned storage and disposal facilities.

The third subproject, SOS-3.3, dealt with radioactivity in metals and included both measurements and an overview of clearance practices. The work was related to an earlier NKS study on clearance [4]. The objective of the SOS-3.3 subproject was to investigate contamination levels in commercially available metals. This will provide a basis for assessing the radiological consequences of clearance and recycling of scrap metal.

Subproject SOS-3.1 and subproject SOS-3.2 were slightly modified compared with the original proposed project plans [5]. Owing to less financial support than originally proposed, a subtask on international guidance and a subtask with case studies were excluded from SOS-3.1. The plans for subproject SOS-3.2 were originally based on the fact that disposed drums at Kjeller should be retrieved and studied during the programme period. However, the digging up of the drums was postponed and the experiences of retrieval within SOS-3.2 were limited to the digging up of a few drums in 1993.

Figure 1 illustrates the connections between the SOS-3 subprojects. SOS-3.3 was a project within the clearance field, SOS-3.2 dealt with intermediate storage of Low Level Waste (LLW) and Intermediate Level Waste (ILW) and SOS-3.1 dealt with disposal in future repositories.

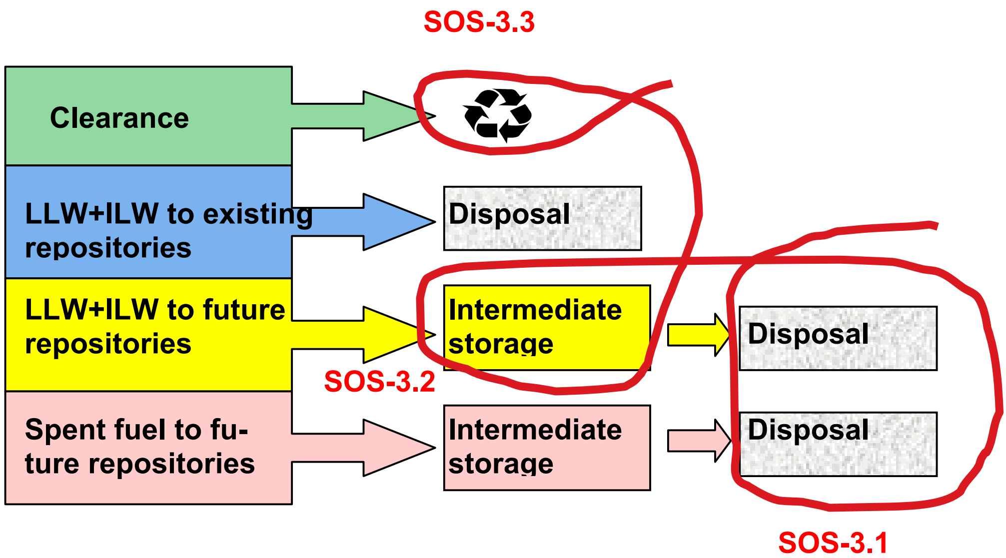

Figure 1. The areas of the SOS-3 subprojects are enclosed by a red line. SOS-3.1 dealt with disposal in future repositories, SOS-3.2 dealt with intermediate storage of Low Level Waste (LLW) and Intermediate Level Waste (ILW), and SOS-3.3 was a project within the clearance field.

2 Environmental Impact Assessment (SOS-3.1)

Four Nordic seminars on EIA (Environmental Impact Assessment) for radioactive waste repositories were arranged within the SOS-3.1 subproject during 1998-2001 [6-9]. Three similar seminars have previously been carried out within the NKS project AFA-1 [10-12]. Thus a total of seven EIA seminars have been arranged. The seminars were held in Iceland in 1995, Finland in 1996, Sweden in 1997, Norway in 1998, Denmark in 1999, Iceland in 2000 and Finland in 2001. The seminars mainly focused on experiences from EIA procedures for the disposal of radioactive waste, although experiences from other EIA processes were also presented and discussed. The latest seminar was arranged in co-operation with the NKS project SOS-1.

Some experiences from EIA processes in the Nordic countries, based on presentations given at the seminars in 1998-2001, are presented in the following sections.

2.1 EIA systems in the Nordic countries

EIA was introduced into national legislation in the Nordic countries during the period 1987-1994, either by separate legislation and regulation or inclusion in other acts. All of the Nordic countries have introduced new legislation or made amendments to include the requirements made in the EU Directive 97/11/EC, which introduces changes to the previous directive 85/337/EEC. In Denmark, a planning act with revised provisions on EIA became effective in June 1999. In Finland, the act on environmental assessment procedure of 1994 has been revised and the amendments in the act became effective in April 1999. In Iceland, a new act on EIA took effect in June 2000. In Norway, new regulations on EIA were introduced by a royal decree in 1999. The Swedish Environmental Code (Miljöbalken) entered into force in 1999 and introduced the first overall requirements in Sweden for EIA procedures, and amalgamates different acts in the environmental field. The changes introduced by the directive 97/11/EC are embodied in the Environmental Code and in regulations.

The EIA processes are handled in different ways in the different Nordic countries even if internationally accepted principles are adopted [10]. The role and responsibility of the developer, the actors at national level (ministries, national agencies), the regional authorities (regional councils, county administrative boards) and the local level authorities differ between the national EIA systems. Table 1 shows the actors responsible for different parts of the EIA processes in the Nordic Countries [8]. The different parts of the EIA processes are based on the structure of the different elements of the EU directive 97/11/EC:

- Screening: Deciding which projects require an environmental impact assessment to be carried out narrows the application of EIA to those projects that are considered likely to have significant environmental impacts.

- Scoping: Identifying at an early stage, the nature and scale of potential environmental impact arising from the proposed development and from all of the project's possible impacts, assessing what are the key, significant issues, and what studies are required to establish their significance.

- Notification: Making the EIS public and available for comments.

- Public participation and consultation official bodies: During the EIA process, encouraged by authorities or required by legislation and or regulations as part of scoping phase or preparation and/or review of the EIS.

- EIS review: determine whether the report meets legal or regulatory requirements, whether the terms of reference provide a satisfactory assessment of the proposal, and contains the information required for decision-making.

- Decision: official decision on the project, made on the basis of the EIS report and other material.

An example of a procedure for environmental impact assessment is given in Figure 2.

Table 1. Actors responsible for parts of the EIA processes.

	Denmark	**Finland**	**Iceland**	**Norway**	**Sweden**[1]
Screening	The Regional authority (Amt)	The Ministry of the Environment The Ministry of Trade and Industry[2]	The Planning Agency	The competent authority	The County Administrative Board (Länsstyrelsen)
Scoping	The Regional authority (Amt) Minister for the Environment	The Regional Environment Centres The Ministry of Trade and Industry[2]	The Planning Agency	The competent authority with consultation with the Minister of the Environment.	The operator ensuing consultation with the County Administrative Board and other authorities
Preparation of the EIS	The Regional authority – in some instances the developer	The developer, in some instances the regional authority	The developer	The developer	The developer
Notification	The Regional authority (Amt)	The Regional Environment Centres The Ministry of Trade and Industry[2]	The Planning Agency	The competent authority	The County Administrative Boards or the Environmental Courts
Review	The Regional authority (Amt), the relevant Ministry and the Minister of the Environment	The Regional Environment Centres The Ministry of Trade and Industry[2]	The Planning Agency	The competent authority	The County Administrative Boards or the Environmental Courts
Decision-making authority	The Regional authority (Amt)	The competent authority	The Planning Agency	The relevant planning- or license granting authority.	The County Administrative Boards or the Environmental Courts
Decisions on appeal	The Nature Protection Board of Appeal	The Supreme Administrative Court (rules on the MoE screening decision)	The Minister of the Environment	No possibility for appeal	The Environmental Court, the Superior Environmental Court and the Supreme Court

[1] The table identifies the steps in the EIA according to the Environmental Code. For nuclear activities, an EIA should also be carried out according to the Act on Nuclear Activities. This Act also identifies the nuclear regulators as important actors throughout the EIA

[2] For nuclear energy projects

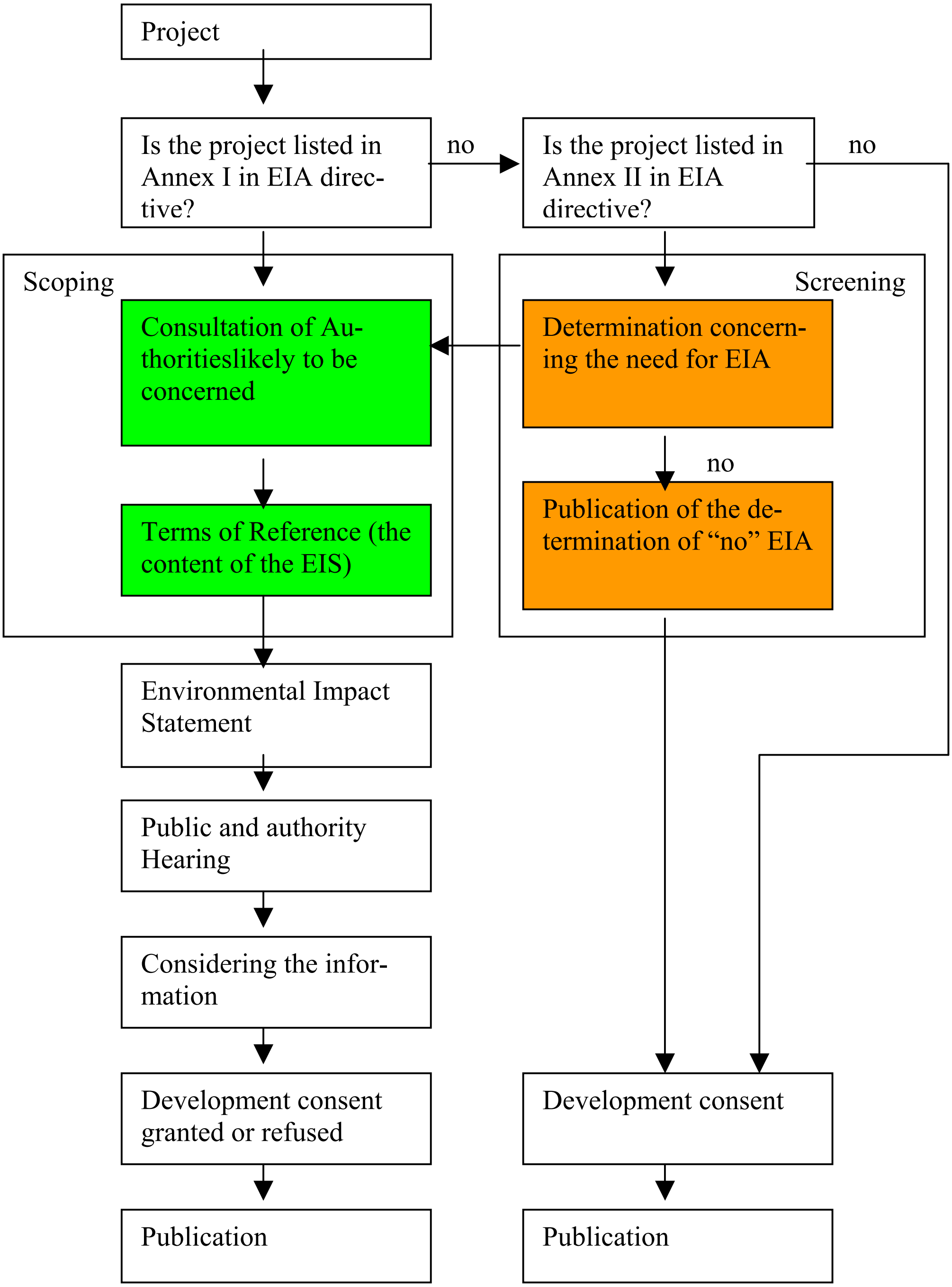

Figure 2. The procedure for environmental impact assessment in Denmark [9]. The procedure is based on requirements in EU directives and conventions (the Espoo Convention on effects across national borders and the Århus Convention on information to citizens).

2.2 Experiences from Denmark

Low- and intermediate-level radioactive waste in Denmark is collected, treated and stored at the Risø research centre, while spent nuclear fuel is returned to the USA. The policy has been to postpone the disposal of Danish radioactive waste until future complete decommissioning of the nuclear research facilities at Risø, notably the DR3 reactor. After closure of this facility in September 1999, comprehensive planning for decommissioning to green field of all the nuclear facilities at Risø was initiated.

A study on the technical and economic aspects of decommissioning the nuclear facilities at Risø has been made [13]. Three decommissioning scenarios were considered with decay times of 10, 25 and 40 years for the DR3 reactor. The results from the study indicate that there will not be much to gain by allowing for the longer decay periods, since some operations still will need to be performed remotely.

An assessment of the amounts of radioactive waste to be transferred to a Danish repository was also included in the study. The waste to be brought to a repository will be of the low-level and intermediate-level type. The main activity comes from relatively short-lived radioisotopes (up to 30 years half-life) but some waste will contain long-lived actinides and β-emitters. The repository volume required has been estimated at 3000-10000 m^3. Besides the radioactivity in the waste, the disposal facility must also be able to accommodate chemically toxic materials such as beryllium, cadmium and lead. In addition to holding the waste arising from the decommissioning of the facilities at Risø, the repository must accommodate radioactive waste that continues to come from hospitals and industry.

A formal EIA of the decommissioning project is not required. However, the establishment of a Danish repository for radioactive waste would require an EIA. It would then be valuable to benefit from experiences from performed EIA processes from non-nuclear projects. Denmark has, for instance, experiences from EIA processes for projects on stores for natural gas, gas pipes, overhead electric cables and disposal of hazardous waste. Some general experiences from these processes are valid for many EIA processes in Denmark and in the other Nordic countries [7]:

- An EIA process may take a very long time.
- A lot of research is often required.
- It is better with too much than too little information.
- Communication of potential risks is very important.
- It is important to involve different stakeholders early in the process.

2.3 Experiences from Finland

The objectives and timetable for the Finnish nuclear waste management programme have been defined in a policy decision by the Finnish Government in 1983. Initially the two Finnish nuclear utilities adopted different spent fuel management policies. The IVO company (presently Fortum Power and Heat Oy), operating the Loviisa nuclear power plant, had a contractual agreement for the entire fuel cycle service from the former USSR and subsequently from Russia, including return of spent fuel. The other utility, Industrial Power Company TVO operating the Olkiluoto nuclear power plant, has consistently favoured as its main option the final disposal of spent fuel in a repository in Finland. The amendment of the Nuclear Energy Act in 1994 stipulated that all radioactive waste produced in Finland - including spent fuel from both nuclear power plants - has to be processed and disposed of in Finland.

The repositories for low- and intermediate-level radioactive operational waste from the Finnish nuclear power plants in Olkiluoto and Loviisa were brought into operation in 1992 and 1998 respectively. The repository at Olkiluoto is also used for intermediate storage of radioactive waste from research activities, hospitals and the non-nuclear industry. The disposal plans for wastes from decommissioning of the NPPs are based on the extension of the on-site repositories for reactor wastes.

According to Finnish legislation, a nuclear facility such as a spent fuel disposal plant, requires a Decision in Principle (DiP). This first licensing stage has to be implemented according to two laws; the Nuclear Energy Act of 1987 and the Act on Environmental Impact Assessment Procedure of 1994. According to the Nuclear Energy Act, the application for the DiP must include an Environmental Impact Assessment (EIA) report for the planned facility. In considering the DiP, the Finnish Government shall consider whether "the construction project is in line with the overall good of society". For the decision, the Radiation and Nuclear Safety Authority, STUK, has to make a preliminary statement on the safety of the facility, and the host municipality must state its acceptance of siting the facility. A positive DiP can only be made by the Government if the municipality's statement is favourable. Finally the decision has still to be endorsed by the Parliament.

In early 1980s, TVO launched a long-term stepwise programme, aiming at the disposal of spent fuel in a deep geologic repository in Finland. In 1995, the power companies founded a joint company, Posiva Oy, which took charge of implementing the spent fuel disposal programme in 1996. According to the long-term plan, the choice of the site for the spent fuel disposal facility was scheduled to be made during 2000. The selection process for a spent fuel disposal site in Finland is depicted in Table 2.

Table 2. The stepwise site selection process for the spent fuel disposal facility in Finland.

1985	Based on countrywide site screening, 102 potentially suitable areas were identified.
1987	Five areas, including the Olkiluoto NPP area, were selected for the preliminary site investigations.
1992	The three most appropriate sites (Romuvaara at Kuhmo, Kivetty at Äänekoski and Olkiluoto at Eurajoki) were included for detailed investigations.
1997	Site investigations were also started at the Loviisa NPP site.
1997 - 1999	Environmental impact assessment (EIA) procedure was conducted in the four municipalities.
May 1999	Posiva submitted to the Government a Decision in Principle (DiP) application, where Olkiluoto is proposed as the disposal site.
January 2000	STUK submitted its preliminary safety appraisal related to the DiP application.
January 2000	The host municipality, Eurajoki, of the Olkiluoto site gave its approval to the DiP application.
November 2000	The Supreme Administrative Court rejected the two appeals on the municipality's decision (rejected earlier by the regional Administrative Court in Turku).
December 2000	The Government made a favourable Decision-in-Principle.
May 2001	The Parliament ratified the decision with a clear majority. (with votes 159 vs 3).

The multi-phase process for selecting the site for a spent fuel disposal facility has lasted about two decades. During the whole process, the developer, first TVO and subsequently Posiva, has had active contacts with the decision-makers and the general public in the candidate municipalities. In fact, both the Nuclear Energy Act and the EIA Act require that public hearings have to be arranged. The site selection process culminated in the combined EIA and DiP processes during the years 1997 to 2001.

Posiva Oy started the formulation of the EIA programme at all four candidate sites (Eurajoki, Kuhmo, Loviisa, Äänekoski) in early 1997. At this stage, a comprehensive public interaction programme was launched, consisting of a large number of public meetings and brainstorming sessions, distributing various printed material and videotapes and different presentations at local fairs and other public gatherings. The EIA programme was officially submitted to the Ministry of Trade and Industry (the contact authority) in February 1998 and, on the basis of public hearings and comments from a number of stakeholders and expert bodies, the Ministry gave its statement on the programme in June 1998. In accordance with the Espoo Convention, the neighbouring countries Sweden, Russia and Estonia were notified of the EIA programme.

Posiva Oy submitted the completed EIA report together with a comprehensive set of supporting documents to the Ministry of Trade and Industry in spring 1999. After that, the Ministry asked for statements from local and national authorities and opinions from the public on the EIA report. After the hearings, the Ministry issued its statement in November 1999, which completed the EIA process.

At the same time as the EIA report was submitted to the Ministry in May 1999, Posiva Oy submitted the Decision in Principle (DiP) application to the Government. The DiP application addressed only one site candidate in the vicinity of the Olkiluoto NPP site in the Eurajoki municipality. As described in Table 2, the DiP process was completed in May 2001, when the Finnish Parliament ratified the Government's decision.

The EIA and DiP processes were quite demanding for both Posiva and the authorities. The Public Sector's Research Programme on Spent Fuel Management had a significant role in supporting the activities of the authorities in these processes [14]. The support included, among other things, assistance in developing the basic EIA procedures, follow-up of the EIA and DiP processes, evaluation of the key documents produced by Posiva Oy, and providing impartial special reports on spent fuel management for a non-technical audience.

After the positive conclusion of the DiP process, the planned next stage of the Finnish final disposal programme will include an underground research facility ONKALO in Olkiluoto, the construction of which is scheduled to start within a few years. The construction of the disposal facility is scheduled to start in early the 2010s and the actual final disposal activities would start some ten years later. These implementation stages will, however, need a construction licence from the Government, and later a separate operating licence.

2.4 Experiences from Iceland

The growing international tendency that each country should manage its own waste makes it important not only to consider international solutions for the disposal of radioactive waste from Iceland but also to study the possibility of finding a suitable disposal site in Iceland. However, Iceland is situated in one of the most volcanically active and seismic regions in the world, and it is therefore hard to find a satisfactory disposal concept in the country.

Iceland has carried out an on-going and planned non-nuclear projects of interest from the EIA point of view, for example projects on:

- construction of dams
- power lines
- forest cultivation
- hydro-electric power stations
- geothermal power stations

2.5 Experiences from Norway

Norway has a combined disposal and storage facility at Himdalen in Aurskog-Høland. The facility is used for long- and short-lived low level radioactive waste. When the facility is closed, it will be decided whether to retrieve the stored waste or to convert this part of the facility into a repository as well. No decision has been taken on the disposal or future management of spent nuclear fuel. The spent fuel elements are presently stored at Halden and Kjeller.

The licence for the construction of the facility at Himdalen was received in 1996 and the facility was finished in 1998. One lesson learned from the licensing process was that the information on the project to the municipality could have been better, for example regarding [6]:

- Why Himdalen was selected from some 50 alternatives.
- Is the waste really harmless? Would it then not be better to place the facility near a big road?
- Advantages for the municipality (no new jobs were created).

The Swedish Radiation Protection Institute and the Swedish Nuclear Power Inspectorate were also involved in the licensing procedure for the combined disposal and storage facility at Himdalen, which is close to the Swedish border. The licence application was sent from the Norwegian Radiation Protection Authority to the Swedish Radiation Protection Institute. This was done in accordance with the Nordic Environmental Protection Convention between Denmark, Finland, Norway and Sweden. The County Administrative Boards for the Swedish regions near Himdalen were also informed about the plans for a repository at Himdalen and an information meeting was held in the county of Värmland. The effects on Sweden from the facility at Himdalen were considered as non-existent.

Norway also has some EIA experiences based on Norwegian support of environmental clean-up activities in Russia [9]. One of the objectives of this work is to ensure that the procedures used for the decommissioning of nuclear-powered submarines and radioactive waste management are appropriate and consistent with relevant policies and guidelines adopted by international agencies and/or in other countries. The Russian Federation state regulatory process imposes strict requirements on operators to demonstrate adequate safety, environmental and human health protection. In practice, however, there is little experience in Russia of how to assess coherently and to combine all these different issues within an overall process that leads to informed decision-making. Regulatory requirements and related assessments tend to focus either on safety (prevention of accidents), protection of human health (in normal operations and in the event of accidents) or protection of the environment as distinct from human health, and not on the whole problem.

2.6 Experiences from Sweden

Sweden has a final repository for radioactive operational waste (SFR) at Forsmark, which is a repository for low- and intermediate-level radioactive waste. There is also a central interim storage for spent nuclear fuel (CLAB) at the Oskarshamn nuclear power plant.

Two major facilities will be designed, constructed, sited and licensed within the next 10-15 years: namely a plant for encapsulation of spent nuclear fuel and a final repository for spent nuclear fuel.

The main alternative is to site the encapsulation plant adjacent to CLAB. Other alternatives are under investigation, however, e.g. co-siting with the spent fuel repository. SKB plans to submit a license application for siting and constructing the encapsulation plant in 2005.

The main alternative, KBS-3, for disposal of spent fuel involves emplacement of fuel elements in copper canisters (corrosion resistance) with cast iron inserts (mechanical strength). The canisters are embedded in bentonite clay in individual deposition holes at a depth of 400-700 m in the bedrock.

SKB has carried out feasibility studies for a spent fuel repository in eight municipalities. These studies are entirely based on existing material, i.e. no drillings are made. In December 2000, SKB presented three candidate sites (in the municipalities of Oskarshamn, Tierp and Östhammar) for careful site investigations, including extensive drilling programmes. SKB's proposal was reviewed by SKI and about 60 other organisations, including municipalities, NGOs, government agencies etc. during the winter/spring 2000/2001. In June 2001, SKI reported the review findings to the Government. In parallel with SKI, the Swedish Council for Nuclear Waste (KASAM) also reviewed SKB's proposal and reported to the Government. In November 2001 the Government stated that SKB had provided sufficient material for continuing with site investigations in the proposed candidate sites. Based on SKB's material, the reviews and the Government's decision, the proposed municipalities will decide whether to participate in site investigations or not. Provided they agree to participate, the site investigations will start in 2002. When the site investigations begin, the EIA-procedure will also commence according to the requirements in the Environmental Code and the Act on Nuclear Activities. It should, however, be stressed that much of the work carried out during the feasibility studies has to a large extent been inspired by good practice for EIA. Most parties (e.g. SKB, SKI, SSI, municipalities and County Administrative Boards) involved in the siting process so far recognise EIA as an efficient and important tool for public involvement.

From SKI's and SSI's perspective, the experience shows that regulators should engage early in the pre-licensing phase, e.g. in EIA and siting, and that this can be done without compromising the independence and integrity needed in the licensing phase.

2.7 Discussion and conclusions

The series of seminar arranged within the subproject and its predecessor in the subproject AFA-1 of the previous NKS programme has provide a good forum for different stakeholders to exchange experiences on the environmental impact assessment (EIA) processes. The stages of implementing the EIA procedure have varied among the participating countries. In Finland, the legislation on EIA and its link to the nuclear energy legislation has been clearly defined already in 1994. In Finland there are also many practical applications of the EIA procedure. The most important process has been related to the long-term programme of the site selection for a spent fuel disposal facility. In Sweden the legislation was initially less concentrated, but the further development of the pertinent legislation has considerably clarified the situation. In Sweden there is also long experience on the co-operation and dialogue between the various stakeholders (developer, authorities, municipalities and the public) related to the site selection of the encapsulation plant and the disposal facility. Strictly speaking, the legally formal EIA processes have not yet been started for the nuclear waste projects. However, the carefully conducted preparatory studies will provide a comprehensive basis for the forthcoming EIA programmes.

The other Nordic countries have had less pronounced EIA related processes for nuclear facilities, but the experiences from these processes and similar processes for major non-nuclear projects have also been mutually fruitful to the participants in the information exchange

3 Intermediate storage (SOS-3.2)

Within the SOS-3-2 project, a study on intermediate storage of radioactive waste packages in the Nordic countries has been performed [15]. The results from the study are presented in this chapter. Recommendations are given regarding different intermediate storage options as well as control and supervision. The disposal of drums at Kjeller in Norway has also been included. This is an example of an intended (and correctly licensed) disposal facility turned into what in practice has become a storage system. However, facilities for intermediate storage of spent fuel or high-level waste and facilities for decay storage of short-lived radioisotopes were not included in the study.

3.1 Strategies for intermediate storage

The Nordic countries have experiences from different manners of storage of waste packages with low- and intermediate-level radioactive waste: in temperature controlled storage buildings, in unheated storage buildings, in rock vaults, in concrete silos, outdoors, and also storage as a feature in final disposal.

All radioactive waste generated in Denmark since about 1960 is stored at Risø National Laboratory in various types of intermediate storage facilities. Waste units with high external radiation, under safeguard or containing significant amounts of α-emitters, are stored at 'Centralvejslageret'. This is an underground concrete block with holes for 30-litre stainless steel containers, standard 210-litre steel drums, or cellars for larger boxes and other units with contaminated equipment of various types. Low-level waste in 210-litre drums is stored in an unheated storage building (see Figure 3). Previously, concrete silos were used for intermediate storage of this type of waste.

In Finland, the main sources of low- and intermediate-level radioactive waste are the two nuclear power plants. The waste management strategy at the nuclear power plants is based on conditioning, short-term intermediate storage and disposal of these wastes in rock cavity repositories at the power plant sites. The Technical Research Centre has a small research reactor and some laboratory rooms, where radioactive sources are handled. The radioactive waste arising from these practices is packed into steel drums, which are transferred into a purpose-built storage room. The radioactive waste from small-users of radioisotopes is collected and, as necessary, packed by STUK. Until 1997, these waste packages were stored in a bunker located in the Helsinki area (see Figure 4). In 1997, the small-user waste packages were transferred from this bunker for further intermediate storage into a rock cavity located in the premises of the Olkiluoto repository.

Figure 3. Intermediate storage of drums in an unheated storage building at Risø in Denmark.

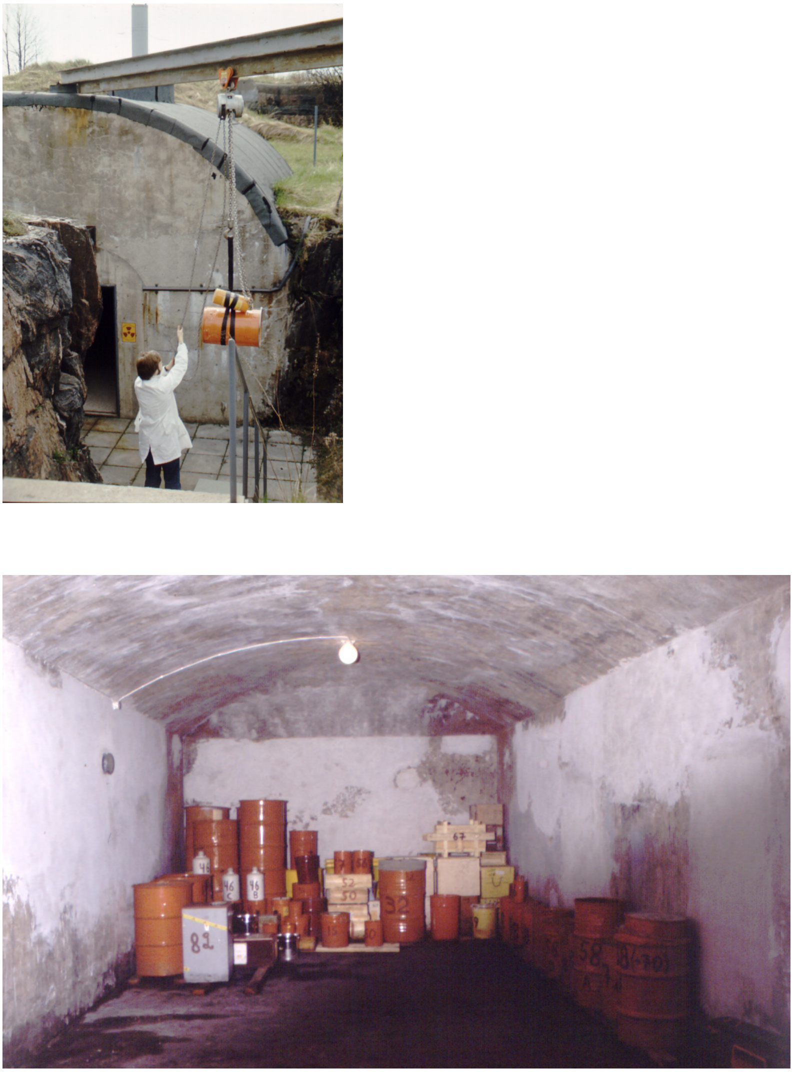

Figure 4. Partly underground bunker used 1973-1997 for intermediate storage of radioactive waste from small-users in Finland.

There are no nuclear installations in Iceland. Radioactive waste is only generated in very small quantities in medicine, research and industry. However, a few discharged smoke detectors are stored at the Icelandic Radiation Protection Institute, and some metal or metal encapsulated sources no longer in use are in the possession of their owners [1].

The facility for waste treatment and storage at Kjeller in Norway receives low- and intermediate-level radioactive waste from two research reactors, radioisotope production and from external users of radiation sources. Low- and intermediate-level radioactive waste has been temporarily stored in two separate buildings at the IFE-Kjeller site (see Figure 5). During the spring of 1999, transfer of waste drums to the new combined storage and repository for low- and intermediate-level radioactive waste in Himdalen was started.

Figure 5. Intermediate storage of drums in a heated storage building at Kjeller in Norway.

In 1970, about 1000 drums with radioactive waste were buried in clay at Kjeller. When the drums were buried, this method was recommended by the IAEA and was in accordance with contemporary international practice. Radiation protection policy has changed since then, however. When the Norwegian parliament in 1994 made a decision on building of the combined storage and repository for low- and intermediate-level radioactive activity waste at Himdalen, it was also stated that the drums should be retrieved and transferred to this new repository.

The Final Repository for Radioactive Operational Waste, SFR, in Sweden has been in operation since 1988. SFR is used both for disposal of operational waste from the nuclear power stations in Sweden and of similar waste from Studsvik. The nuclear power stations in Forsmark, Oskarshamn and Ringhals and also AB SVAFO at Studsvik have in addition shallow land burial facilities for very low-level short-lived radioactive waste. Some short-term interim storage of waste packages takes place in buildings or in transport containers, before transfer to the SFR or to the shallow land disposal facilities. However, part of the waste packages produced at Studsvik have to be intermediately stored for a longer time, since they have not been accepted for final disposal in the SFR. An unheated storage building owned by AB SVAFO is used for intermediate storage of old steel drums with low-level waste at Studsvik. An underground purpose-built rock facility owned by AB SVAFO is used for intermediate storage of waste packages with intermediate-level radioactive waste at Studsvik. Both 200-litre steel drums and concrete containers (external dimensions 1.2×1.2×1.2 m) are placed in the store (see Figure 6). The waste will after the intermediate storage be transferred to SFR or SFL as appropriate. However, most packages will possibly be transferred to SFL. The existing rock vaults at Studsvik are not intended to be used for final disposal.

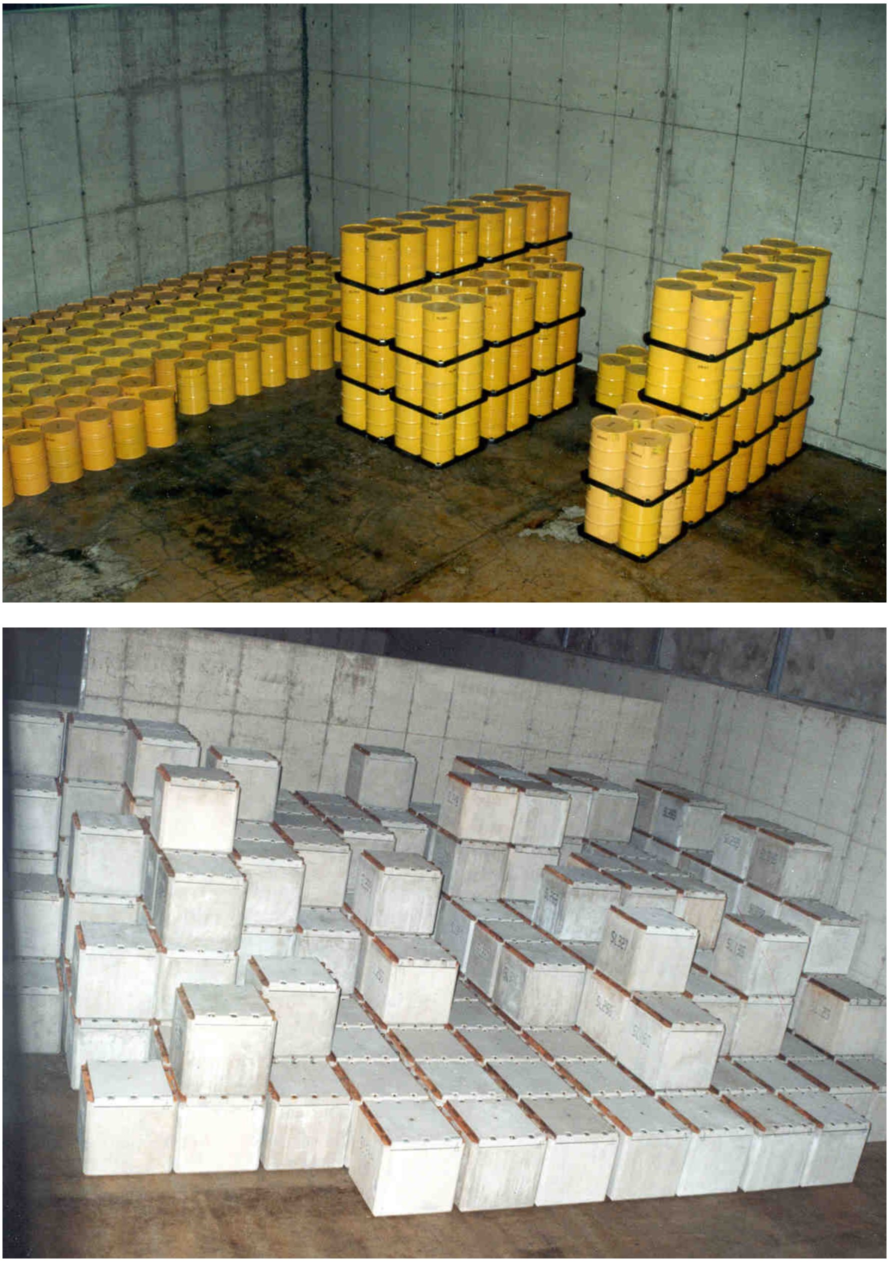

Figure 6. Intermediate storage of drums and concrete containers in rock vaults at Studsvik in Sweden.

3.2 Experiences regarding intermediate storage options

Some general recommendations for design and operation of storage facilities derived from the Nordic experience are presented below [15].

3.2.1 Outdoors intermediate storage

Parts of the drums with low-level radioactive waste at Studsvik have been stored outdoors until 1977, when an unheated storage building was built. Although the drums were probably in rather good conditions when they were transferred to the storage building, they later became very corroded. The drums have been reconditioned and put into outer drums.

At Risø a few hundred drums with low-level waste were also stored outside from about 1960 to 1966. This was considered unsatisfactory due to the onset of corrosion, and the drums were transferred to the silos system described in the following section.

In wet climates typical of the Nordic countries, longer periods of outdoor intermediate storage of waste drums cannot be recommended. If for any reason the capacity in storage buildings is less than the storage volume required, a solution could be to place the drums in standard freight containers.

3.2.2 Intermediate storage in silos made from concrete rings

Drums with Danish low-level waste were for about 20 years stored in the modular silo system. The system was found to be unsatisfactory due to water intrusion and generally high humidity inside the silos. The drums have now been transferred to a new storage facility.

The silos were constructed from standard concrete rings like those used for wells in sewage systems. Each silo contained 12, or later 21, drums stacked in three layers This modular system was selected in order to avoid initial investment in a conventional storage building.

The experience with the Danish silo system illustrates the bad effects of prolonged storage of waste drums in a wet environment. The problems were aggravated by the presence of drums containing unconditioned evaporator concentrate. Bituminised evaporator concentrate is less problematic, but shows in a humid environment the swelling behaviour expected from experimental work [16,17].

In general, the possibility of water uptake from high humidity air into hygroscopic waste should be kept in mind.

The silo system cannot be recommended. Moreover, other systems should be carefully evaluated for humidity problems before they are used for long-term intermediate storage.

3.2.3 Intermediate storage in unheated storage buildings

At Studsvik in Sweden, an unheated storage building owned by AB SVAFO is used for intermediate storage of drums with low-level radioactive waste. The store contains drums that have been reconditioned. The reconditioned drums are placed vertically in four layers with shuttering plywood between each level (see Figure 7). New drums have not been placed in the building since 1988. All new drums with low-level solid waste are now transported to the SFR and long-lived low-level radioactive waste is treated as intermediate-level waste and packed in concrete containers with double-lid drums. The concrete containers are placed in rock vaults for intermediate storage (see Figure 6).

Figure 7. Reconditioned old drums with low-level solid radioactive waste in an unheated storage building at Studsvik.

In Denmark, an unheated hall construction is used for storage of waste drums at Risø (see Figure 3). The drums are stacked in four layers. Originally the building was designed with a lot of natural ventilation, but that gave rise to condensation on the cool drum surfaces when the weather changed from a long cool period to warmer conditions with more moisture in the air. The water collected on the lids of drums in the lower layers, and took a long time to evaporate. Under such circumstances the orientation of the drums can be important; if the drums had been lying on their sides, the collection of pools of water would not have been possible. External corrosion was beginning around the bottom of the drums in particular. The problem was eliminated by installation of air drying equipment combined with drastic reduction in natural ventilation. However, there is still some risk of condensation in the middle of the stacks.

In general, it is the Nordic experience that storage of waste units in unheated and not thermally-insulated storage buildings may lead to corrosion of steel drums due to the condensation of water on the drum surfaces. Too much air exchange should be avoided and some type of air-drying equipment may have to be installed to reduce the air humidity.

3.2.4 Intermediate storage in heated storage buildings

A facility with a moderate amount of temperature control is the simple interim storage for radioactive waste used for storage of small-user waste from 1973 until 1997 in Finland (see Figure 4). The storage is located at the Santahamina Island in the Helsinki area. The island is a military area, and the storage facility is a partly underground bunker that was earlier used for storing ammunition. The storage was operated by the STUK, which collected and, as necessary, also packed radioactive waste from small-users. The storage facility had a simple ventilation system and a heating system so that the temperature could be kept slightly over 10 ^{o}C even in wintertime. The waste packages remained in a fairly good condition during their storage time of 24 years at the maximum. A major disadvantage was lack of space, which complicated the handling of waste packages and caused unnecessary radiation exposure.

In Norway there is positive experience with intermediate storage of radioactive waste units in temperature-controlled storage buildings at Kjeller (see Figure 5). The temperature in the two IFE storage facilities is controlled by central heating in the winter. Typically, the temperature will be around 20 ºC, but may vary from 15 ºC to 25 ºC. The waste drums are thus never subject to frost or excessive heat. Both storage facilities have continuous air ventilation. Experience from the storage is that the containers are kept dry under all circumstances. This form for storage is considered to reduce the risk of degradation of the waste containers and can therefore be recommended.

3.2.5 Storage in rock vaults

Sweden has positive experiences of storage of intermediate-level radioactive waste units in rock vaults at Studsvik (see Figure 6). The interim store at Studsvik has the following advantages:

- The rock provides good shielding.
- This type of store is no more expensive to build than an above-ground storage building for intermediate-level waste.
- The temperature in the store is almost constant throughout the year without heating (about 13 ^{o}C).
- The leakage of groundwater into the store is low.
- The humidity of the air in the store does not exceed 60 %. Dehumidification equipment is automatically turned on if the humidity increases.
- The store is equipped with a safety ventilation system. This can be used if the air in the store becomes contaminated. The exhaust air is then released through a high-efficiency filter.

Each waste package with intermediate-level waste is transported to the store in a special shield and then taken out from the shield and transferred to a selected place in a concrete compartment by remotely controlled equipment. The compartment consists of three parts. Drums with solidified sludge are placed in one part, while concrete containers with solid waste are placed in the two other parts. A watertight roof over the compartment is inspected regularly. No defects have been observed.

The packages with intermediate-level waste can only be inspected by TV cameras, but-some drums with solidified sludge have less radioactive contents and can be handled when unshielded. About one year ago, some of the drums with low radioactivity content showed corrosion spots on the drum surfaces. The holes have now been sealed. No other signs of degradation of the waste packages have been observed.

This type of intermediate storage in rock vaults can be recommended provided that the store can be built in a suitable crystalline rock.

3.2.6 Storage as a feature in final disposal

In licensing final disposal systems, it is becoming more and more common to require certain possibilities for retrieval of the waste. The requirement can be for a certain part of the waste – as specified, for example, for Himdalen in Norway – or it can cover a certain period before the facility, which initially is regarded as a temporary store, is converted into an actual disposal facility.

About 1000 drums buried in a field at Kjeller in Norway have now been retrieved. This is an example of an intended disposal facility turned into what in practice has become a storage system. When the drums were buried in 1970, this method was recommended by the IAEA and was in accordance with contemporary international practice. Radiation protection policy has changed since then, however. When the Norwegian parliament in 1994 decided to build a combined storage and repository for low- and intermediate-level radioactive activity waste in Himdalen (KLDRA), it was also stated that the drums should be retrieved and transferred to this new facility.

The waste drums were buried in two layers in clay (see Figure 8). The radioactive waste consisted of laboratory waste, organic liquid waste absorbed in vermiculite and dried ion exchange resins. Metallic waste was embedded in concrete. For high dose rate waste, the drum was equipped with a lead inner container.

When the drums were buried, it was intended that they should be left in the clay and that it should function as a repository. It was calculated that the outer drum would have a lifetime of ten years and the concrete would constitute an intact barrier for many years on.

In 1993, representatives from the Bellona environmental foundation committed a forced entry to the premises and dug up some drums, one of which was damaged by the mechanical digger. IFE took advantage of the incident and dug up five drums for inspection. In addition, 10 drums were retrieved in 1994. Following the retrieval in 1994, a systematic survey of the repository and the drums was initiated. The drums in the upper layer were in remarkably good condition. Drums from the lower layer had corroded, however, and for some units the outer drum had been penetrated.

Retrieval of the rest of the buried drums started in August 2001 and has now been completed. Figure 9 shows a drum that was lifted out from the repository. Clay on the drum surface was mechanically removed before the drum was lifted into a new drum. The new drum has a volume of 300 litres. The space between the old and the new drum was filled with concrete prior to transport to KLDRA.

Carefully planned storage in a facility that can eventually be turned into a disposal system is a perfectly acceptable option from the technical point of view, although the need for remedial action involving retrieval of old waste from small ad hoc disposal facilities should be avoided as far as possible.

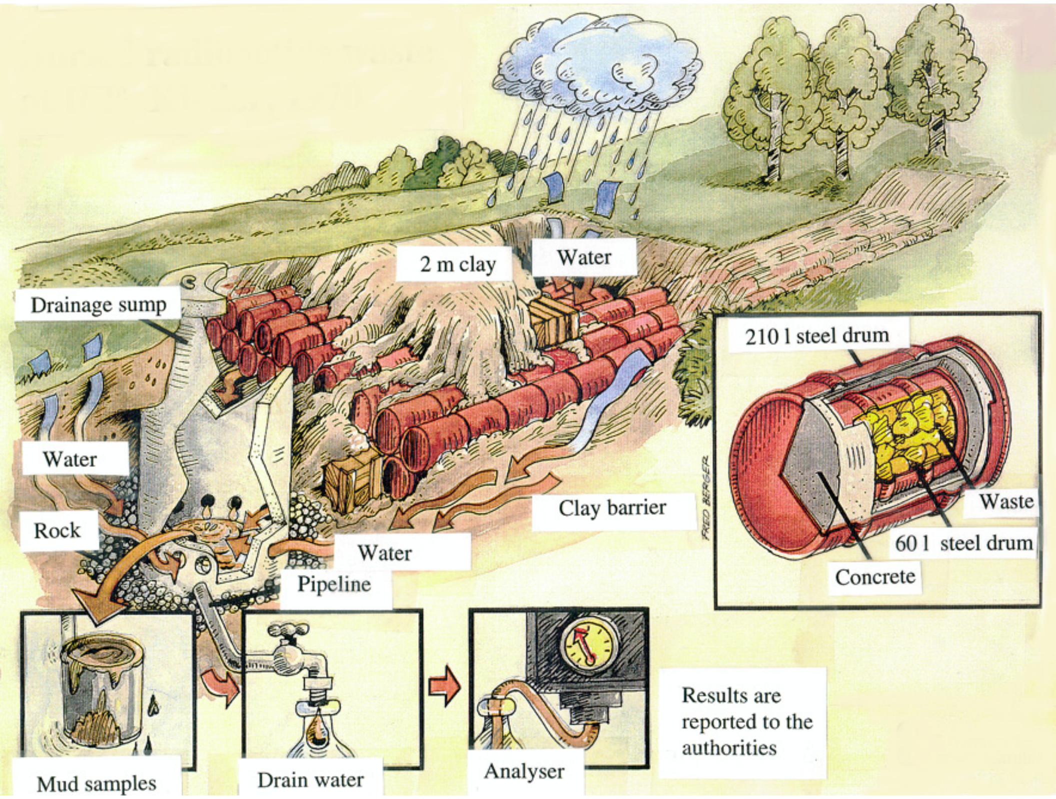

Figure 8. The near surface repository at Kjeller in Norway.

Figure 9. Retrieval of disposed drums at Kjeller .

3.3 Experiences regarding control and supervision

A storage system must be constructed, controlled and supervised in such a manner that the safety and radiation protection of the operating personnel and the general public is ensured. These considerations should encompass the consequences of normal operations as well as reasonable accident scenarios and the prevention of unauthorised removal of the waste materials. The necessary precautions will be very dependent on the type of waste.

3.3.1 Radiation protection

The conditions set by the national licensing authorities must be followed. This may for example involve requirements on admittance, labelling, personal dose control, dose rate monitoring, airborne activity monitoring and contamination control.

3.3.2 Discharge control

Radioactive waste is normally conditioned into solid form when placed into the storage containers. The storage containers, typically steel drums or various types of concrete containers, are leakage proof. Leakage cannot, however, be ruled out totally. Corrosion and other processes may degrade the barriers, and radioisotopes may eventually find their way outside the storage building. An environmental monitoring programme covering the surroundings of the interim storage facility may therefore be desirable.

3.3.3 Work environment and conventional safety

Conventional safety during work carried out in a storage facility for radioactive waste units must also be considered. The waste units are heavy, and transportation and stacking are carried out using heavy equipment. Conventional accidents involving falls of personnel, equipment or waste units could well be the most risky part of operating such stores. It is important to ensure that the operators are competent, take no chances, and know how to use cranes, trucks etc. Stacking of the waste units must be conducted in such a way that there is no risk of instability. Lighting in the store should be sufficient.

If personnel have to stay in an interim store for longer times, conventional work environment aspects must also be taken into consideration. Temperature and draught are one aspect, but the risk of chemicals evaporating from the waste may also have to be considered. Dust is another possibility, and the interim storage building for low-level radioactive waste at Studsvik, for example, has a concrete floor that had to be covered with a special paint in order to decrease the silica concentration in the air.

Safety of the workers is of primary concern, but safety of the installation is also important. The risk is primarily financial, because accidental damage may be difficult to repair. This is especially the case for intermediate-level wastes when access to the storage area is limited and operations have to be carried out remotely or using heavy shielding.

3.3.4 Supervision

During intermediate storage, it is desirable to be able to supervise or otherwise control the condition of the stored waste units, but possibilities for this must be planned in advance. Direct visual inspection is prevented in some facilities by high radiation levels, but in this case some inspection may then be conducted by means of television cameras.

A commonly encountered problem is that the waste units are stacked in such a manner that the outer ones prevent direct access to the inner ones. The advantages are savings in space and cost, and the fact that outer low-level units may serve as shielding for inner ones with higher radiation, but the disadvantage is that observation of the inner units is prevented.

A formal system is advisable for reporting the results of the supervision of waste units and the general state of the storage facility.

3.3.5 Physical protection and security

As a waste, radioactive waste is by definition of no value. However, some types of waste may contain fissionable material and as such will be under the safeguards systems operated by IAEA and Euratom. Physical protection against theft, other diversion or dispersal of such materials will have to be provided in accordance with the rules set up by these organisations.

Radioactive waste units have a certain fascination and may be misused for propaganda purposes. One example is the excavation of buried drums carried out by the Bellona environmental group at Kjeller in 1993. Some protection in the form of guards, fences, locks and intruder alarms against incidents of this type is motivated, one reason being to prevent damage to the activists themselves.

Accidental misplacing of large and heavy packages with conditioned radioactive waste is not very probable, but an easily understandable and wear- and corrosion-resistant marking of the units should be considered.

As for other nuclear facilities, the risks from reasonable accident scenarios may have to be considered. Fire is probably the most important. Conditioned waste is often not combustible, or is at least extremely difficult to ignite, but the presence of unnecessary organic materials inside or near the storage facility should be avoided. The risk of fire may constitute a reason for not siting storage facilities in the immediate vicinity of buildings that have other purposes.

In addition to the waste itself, information about the waste needs to be protected. In connection with improving storage of old radioactive waste, a parallel effort concerned with improving the level of information about the waste is often conducted. For new as well as old waste units in intermediate storage, it is important to ensure the continuing existence of all relevant information. This means that the waste units should be clearly marked at least with numbers (which are not easily lost due to corrosion, for example) and that the associated information specifying contents of radioisotopes etc. is stored securely in suitable databases until it is needed in connection with disposal of the waste. The special problems associated with long-term availability of such information have been studied in an earlier Nordic study [18].

3.4 Discussion and conclusions

Together the Nordic countries cover a wide range of radioactive waste production as well as management practices and possibilities. Sweden and Finland have nuclear power reactors, Denmark and Norway have waste from nuclear research, while Iceland has only very small amounts from the use of radioisotopes in medicine etc. Sweden, Finland and recently Norway are using engineered, near-surface cavities in crystalline rocks for disposal of low- and intermediate-level waste. This is not possible in Denmark, where other possibilities are under evaluation. Even if disposal facilities for low- and intermediate-level waste are available – as for example in Sweden for many years – there may still be a need for temporary storage of long-lived waste that is not suitable for near surface disposal.

A variety of practical solutions have been used for waste storage in the Nordic countries. Together they probably cover most of the technical possibilities. The experience obtained from the facilities also varies widely from quite satisfactory (e.g. in Norway) to behaviour where remedial action has been necessary to maintain satisfactory conditions for the stored waste (e.g. in Denmark and Sweden).

The principal feature to take into account is no doubt air humidity, especially when the waste is packed in steel drums. Satisfactory long-term storage in buildings or rock cavities can only be ensured if humidity is controlled by temperature regulation or use of air-drying facilities. An additional requirement is of course that the waste is conditioned in such a manner that internal corrosion of the waste containers is not at problem.

If due regard is paid to such conditions, to standard radiation protection and to conventional safety in handling of the waste units, the storage of low- and intermediate-level waste units should be unproblematic even for long periods.

Storage facilities are by definition reversible: It should always be possible to move the waste units elsewhere. However, requirements about reversibility or partial reversibility are also becoming quite common for disposal facilities. This is, for example, the case for the Norwegian and the Finnish disposal facilities. Recovering waste from near-surface disposal facilities should normally be possible, even if it was not originally intended. Retrieval of drums from the burial facility at IFE, Norway, is one example.

4 Contamination levels in metals (SOS-3.3)

Clearance of radioactive material, in particular scrap metal, is a quite important issue, nationally as well internationally. For example, the IAEA and EU are active in this field [19-21]. The volume of scrap metal cleared for recycling is expected to increase as the nuclear installations grow older and the need for refurbishment and modernisation increases. However, controlled clearance is not the only source of radionuclides in materials and products. Other sources are naturally occurring radionuclides, accidental smelting of radiation sources, fallout from nuclear tests etc.

The authorities need to know the distribution of radioactive substances, naturally occurring as well as those originating from nuclear installations. This knowledge is needed for assessing the radiological consequences of the present situation and changes expected to occur in the future. The subproject SOS-3.3 deals with this subject. The project includes both an overview on clearance in the Nordic countries and a study on radioactivity in commercially available metals [22,23].

4.1 Clearance in the Nordic Countries

4.1.1 Practices in Denmark

There have only been a very limited number of clearances involving waste from Risø. Denmark has not placed any legal constraints on such clearances. Permission will be granted from NIRH (National Institute of Radiation Hygiene) on a case-by-case basis. As a consequence, Risø has to submit an application to NIRH for approval before any clearance.

The approval of clearance will always be given provided that the recipient is informed that the waste has been cleared from a controlled area, and additionally there shall be a written approval from the recipient accepting the waste.

The National Institute of Radiation Hygiene has dealt with two applications from Risø concerning clearance of metal scrap contaminated with small amounts of radioactive material. In both cases NIRH has cleared the material on the condition that the recipient, a Danish steel-melting company, was informed that the material had been cleared from a controlled area. In both cases the steel-melting company refused to receive the metal scrap. As a consequence, the metal scrap is still situated at Risø. Conditional clearance for use inside the Risø area has been issued for other materials such as sewage sludge and crushed concrete.

An order on the Use of Unsealed Radioactive Sources at Hospitals, Laboratories etc. issued by The National Board of Health regulates the amount of solid radioactive waste from non-nuclear activities that may be sent to municipal dumps. The maximum concentration for municipal dumping is 0.01MBq/kg of waste.

The order also regulates the amount of radioactive waste that can be discharged to the public sewage systems or sent to incineration plants. The maximum activity for liquid waste to be discharged into the public sewage system per month per authorisation is 5 MBq, 50 MBq and 500 MBq, respectively for radionuclides ranked according to radiotoxicity with the additional condition that the concentration must not exceed 0.1 MBq/l. For solid waste sent to incineration plants, the maximum activity in every waste bag must not exceed 5 MBq, 50 MBq, respectively 500 MBq ranked similarly and with the additional condition that the dose rate on the outer surface of each bag must not exceed 5 μSv/h.

The regulations mentioned above are given in accordance with The Council Directive 96/29/EURATOM and with Regulations for the Safe Transport of Radioactive Material, Safety Series No. 6, IAEA 1985.

4.1.2 Practices in Finland

In Finland, the main sources of low level radioactive waste are the two nuclear power plants and the Technical Research Centre of Finland (VTT).

Part of the waste generated in the controlled areas of nuclear facilities is so low-level that it can be cleared from regulatory control, and be disposed of or recycled like ordinary waste. Clearance of waste can be unconditional or conditional.

Unconditional clearance is applicable to waste that, due to its low activity, shall not be regarded as nuclear waste. The method for the disposal or recycling of the waste need not then be defined, and fixed activity constraints for the waste are applied.

In the case of conditional clearance, the transferee and the disposal or recycling method for the waste shall be defined and the activity constraints shall be set on the basis of case-by-case consideration. By virtue of Section 10 of the Nuclear Energy Decree, the provisions of the Nuclear Energy Act are then not applicable to the cleared waste.

Detailed requirements concerning clearance of nuclear waste are given in a guide issued by the Radiation and Nuclear Safety Authority (STUK).

The general radiation protection requirements are consistent with the recommendations of IAEA, NEA and EU (IAEA Safety Series No. 89). The waste cleared from one nuclear facility shall not give rise to radiation exposure of the public exceeding an effective dose of 0.01 mSv in a year to the most exposed individuals (members of the so-called critical group), or a collective dose commitment of 1 manSv per year of practice, unless an assessment for the optimisation of protection shows that exemption is the preferred option.

The following activity constraints are applicable to unconditional clearance:

- The total activity concentration, averaged over a maximum amount of 1000 kg of waste, shall not exceed 1 kBq/kg of beta or gamma activity or 100 Bq/kg of alpha activity. In addition, no single item or waste package weighing less than 100 kg may contain more than 100 kBq of beta and gamma activity or 10 kBq of alpha activity.

- The total surface contamination of non-fixed radioactive substances, averaged over a maximum area of 0.1 m^2 for accessible surfaces, shall not exceed 4 kBq/m^2 of beta and gamma activity or 400 Bq/m^2 of alpha activity.

For conditional clearance, activity constraints based on a case-by-case approval by STUK are applied which, however, shall not exceed the following upper limits defined in the Nuclear Energy Decree:

- The average activity concentration in the waste shall be less than 10 kBq/kg.

- The total activity of cleared waste received by a transferee in one year shall be less than 1 GBq and the alpha activity less than 10 MBq.

For unconditional clearance of waste from regulatory control, an application shall be submitted to STUK, in which the origin and characteristics of the waste and the methods to be used for the determination of the activity of the waste are described. After approval of the application, the waste can be removed from the facility as soon as it arises. Unconditional clearance is not applicable to such waste as is highly volatile or flammable, that is of significant practical value, or that can otherwise very easily cause radiation exposure.

For conditional clearance too, an application shall be submitted to STUK. The clearance approval may either apply to a single batch of waste or be constantly valid in case waste arises repeatedly and its disposal or recycling method remains unchanged.

In Finland, the cleared nuclear waste originates mainly from the repair and maintenance works of the nuclear power plants. No decommissioning projects for nuclear facilities are underway or foreseen in the near future. The amount of very low-level metal scrap cleared for recycling varies from a few tonnes to several tens of tonnes per year and per nuclear power plant. This is mainly iron-based material. Occasionally the amount can be considerably higher when large components are dismantled and cleared. For example, about 300 tonnes of brass was cleared after dismantling of the condensers of the Olkiluoto power plant.

The cleared metal scrap has been transferred to Finnish foundries, to be used as raw material. There has been fairly little public concern about clearance of nuclear waste. The foundries have nowadays portal detectors for discovering any radioactive contamination in loads that enter the foundry.

4.1.3 Practices in Iceland

There are no nuclear reactors in Iceland and there is very limited use of radioactive sources with high activity (such sources are mainly used in medical therapy). No accidents involving radioactive contamination of metals are known to have occurred in Iceland. So far no special rules have been set in Iceland for clearance of scrap metal and metal products. The possibility of radioactive contamination of scrap metal has nevertheless been receiving increased attention, both at Geislavarnir ríkisins (Icelandic Radiation Protection Institute), and amongst scrap metal dealers.

The current Icelandic recommendations concerning classification and handling of radioactive waste are based on the joint publication by the radiation protection institutes in the Nordic countries, Application in the Nordic Countries of International Radioactive Waste Recommendations, published in 1986. The ALI values in the publication have, however, been replaced with the current corresponding values for e(50), the specific committed effective dose, and assuming a maximum yearly effective dose of 20 mSv. ALI = 20 mSv / e(50).

The more recent EU and IAEA recommendations are also taken into account informally. Geislavarnir ríkisins is following the growing concern over the possibility of radioactive contamination of scrap metal. This concern may make it necessary to introduce exemption levels for radioactive contamination of metal products. Such levels would be based upon international levels and they would be set after consultation with the other Nordic radiation protection authorities.

4.1.4 Practices in Norway

An order issued by the Norwegian Radiation Protection Authority (NRPA) regulates the release of radioactive waste from hospitals, laboratories etc. One authorised user can each month release, according to authorisation, a maximum of 0.4 MBq, 4 MBq, 40 MBq or 400 MBq respectively, for radionuclides ranked according to radiotoxicity to both the sewage system and the regular solid waste. Only water-soluble materials are allowed to be released into the sewage system. Excreta from patients can be supplied to the sewage system regardless how high the radioactivity is. Liquid scintillation samples are not normally a radiation problem when they go to incineration.

Deposits on the inside of tubes and other equipment in the oil industry can contain increased amounts of natural radioactivity. These deposits are often called LSA Scale (Low Specific Activity Scale) or NORM (Naturally Occurring Radioactive Materials). The amount of scale has increased, due to the age of the oil-production fields. Seawater is injected into the reservoir to maintain the pressure. Scale can occur on the inside of production tubes and other equipment that have been in direct contact with water used in the production. There are two main types of radioactive deposits in the production equipment in the oil industry; carbonate and sulphate deposits. Measurements show that deposits in the oil production can contain concentrations of radioactivity 100-1000 times higher than what is normal in bedrock and soil. The dose rate on the outside of the production tube depends on the thickness and density of the deposits.

Scale with higher activity than 10 Bq/g of ^{226}Ra, ^{228}Ra or ^{210}Pb are classified as radioactive and must be taken special care of. Scale with lower activity than 10 Bq/g for all these nuclides can be released to the environment. This is in accordance to clearance levels given by the EU.

IFE is in accordance with regulations for the use and treatment of unsealed radioactive sources allowed to release radioactive waste into the sewage system. Per month IFE can supply both the sewage system and the regular solid waste with a maximum of 0.4 MBq, 4 MBq, 40 MBq or 400 MBq respectively for radionuclides ranked according to radiotoxicity.

In Norway there is no current practice for clearance of scrap metal and metal products. No such events have occurred in Norway.

The smelting and recycling companies in Norway have had some events where metal products or scrap metal have been detected as radioactive. But no incidents where radioactive contaminated metal/scrap metal/sources etc. have been melted in the production have occurred. This is detected because the portal the metal travels through on its way in and out of the area detects radioactivity. When radioactivity is detected, NRPA shall be contacted. NRPA may then check the product that has been detected as radioactive. When checking the metal, NRPA may use hand monitors, or portable Ge- or NaI-detectors.

In deciding whether the metal is considered as contaminated or not, NRPA will consider exemption levels issued by the EU and IAEA recommendations, as there are no domestic regulations at present.

4.1.5 Practices in Sweden

Clearance is a well-established part of the Swedish system for radioactive waste management. As early as 1982, the Swedish Radiation Protection Authority (SSI) declared that clearance of scrap metal can be permitted if it does not result in significant enhancement of doses to the public or to the personnel handling the material. Present regulations set the limits for the radioactive waste from nuclear facilities that can be exempted from further regulation under the Radiation Protection Act. The regulations also cover unrestricted re-use, as well as deposition at municipal dumping sites and incineration of oil.

The Swedish clearance levels are consistent with results from studies made by OECD/NEA and NKS and with the clearance levels suggested by IAEA and the EU. One of the bases for these levels is the 10 μSv per year individual dose criterion. An individual can be exposed to radiation from several practices, and in order to prevent the total dose from rising above the trivial dose level, each practice should not contribute an annual dose of more than 10 μSv to the individual. The clearance levels for material from nuclear facilities are presented in Table 3.

Clearance can be permitted at higher activity levels after application to SSI. Melted material from Studsvik has for instance, depending on the nuclide composition, been cleared at levels up to 1 Bq/g. One of the conditions was that the material must be re-melted with other material at a commercial smelting plant. The dose criterion used in these cases is the same as mentioned above.

Since the Swedish clearance levels are only intended for small amounts of material, they will be revised in the near future in order to take into consideration larger amounts of waste emanating from the decommissioning of nuclear facilities.

Table 3. Clearance levels for material from nuclear facilities (SSI FS 1996:2).

	Activity concentration		**Total activity**
	gamma/beta	**alpha**	**per NPP**
Unrestricted use	40 kBq/m^2	4 kBq/m^2	No limit
	0.5 Bq/g	0.1 Bq/g	No limit
Deposition at nuclear facility or municipal dumping sites	5 Bq/g	0.5 Bq/g	1 GBq/year
Incineration of oil	5 Bq/g	0.1 Bq/g	0.5 GBq/year

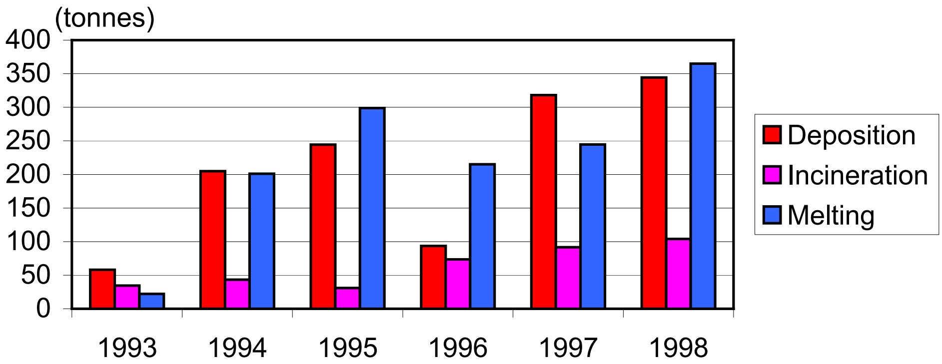

Figure 10. Amount of material exempted from regulatory control in Sweden during 1993-1998, divided according to deposition, incineration of oil or melting of metals .

Figure 10 shows the amount of material that was exempted from regulatory control during 1993-1998 divided according to deposition, incineration or melting. Radioactive waste with low-activity content may be disposed of at ordinary municipal dumping sites. The material is exempted from regulatory control in connection with the deposition at the dumping site. Sludges from sanitary facilities at the nuclear facilities may be deposited on arable land in accordance with conditions stated by the SSI.

Slightly contaminated oil may be incinerated in furnaces designed for destruction of chemicals or in large oil furnaces. In some cases, hazardous waste such as scintillation liquid has been destroyed in the same way.

Melting of metals, mainly steel and aluminium, is performed at the nuclear facility in Studsvik. The resulting ingots are recycled in the metal industry. The melting of scrap material is regarded by the SSI as a suitable path for the recycling of material. However, the steel industry has been reluctant to use the cleared material, and questions have been raised whether it would be possible to sell products that contain cleared material. This reluctance emphasises the need for broadly accepted clearance criteria.

A Swedish Code of Statutes regulates the amount of radioactive waste from non-nuclear activities (hospitals, research laboratories etc) that can be discharged into municipal sewage systems or sent to municipal dumps. The maximum discharge is 10ALImin/month and 1ALImin/occasion or package. A nuclide specific list of ALI values is attached to the Code of Statutes. Most of the nuclides have ALImin in the range of $1 \cdot 10^6$ to $1 \cdot 10^9$ Bq. The amount of solid material released under these premises is about 200-300 tonnes per year.

Occasionally, areas in research laboratories, medical industry etc need to be exempted from further regulatory control. An application to SSI is then required and permission is granted on a case-by-case basis.

4.2 Radioactivity in commercially available metals

A study on radioactivity in commercially available metals was performed in co-operation with metal producers and metal producers' associations within the Nordic countries. Different types of commercially available steel, aluminium and magnesium samples from the metal producers were sent to national laboratories for analyses. The sample weights and dimensions of the samples varied and were in some cases adjusted to, and in other cases not adjusted to, standard dimensions normally used at the different laboratories. For comparison, some other samples were also analysed.

All together roughly 200 steel samples, 70 aluminium samples and 10 magnesium samples were analysed. For comparison, some other samples were also analysed.

4.2.1 Results from gammaspectrometric analyses

All of the samples were analysed using germanium detectors (see Table 4). In most of the steel samples, no activity at all was found. However, five samples showed ^{60}Co concentrations above the detection limits in the range 0.03 – 0.07 Bq/kg. The detection limits were in these cases very low due to long counting times, low background and comparatively high sample weights of 1.6 kg.

No activity at all, or very low activities from natural uranium and thorium, were found in the aluminium and magnesium samples.

Table 4. Results of gammaspectrometric analyses of metal samples.

Laboratory	Samples	Nuclide concentration (Bq/kg)	Uncertainty (%)
Risø	2 steel	Below detection limit (^{60}Co: <0.03)	
Risø	12 steel	^{60}Co: 0.03-0.07	21-70
VTT	100 steel	Below detection limit (^{60}Co: <4)	
IFE	4 steel	Below detection limit (^{60}Co: <0.2-1.0)	
NRPA	2 steel	Below detection limit (^{60}Co: <2)	
Studsvik	67 steel	Below detection limit (^{60}Co: <0.1-0.9)	
Risø	5 aluminium	^{238}U: 4.3-6.5 ^{228}Ra: 0.8-1.6	20 30
VTT	25 aluminium	Below detection limit (^{60}Co: <3)	
Geislavarnir	5 aluminium	^{228}Th /^{232}Th: 0.9 ^{235}U: 0.13 ^{238}U: 2.7	30 30 40
IFE	20 aluminium	^{212}Pb: 1.4-5.8	10-20
IFE	1 aluminium	^{212}Pb: 32.1	10
NRPA	5 aluminium	^{226}Ra: 1.8-8.3 ^{232}Th: 1.5-5.3	10-30 10
NRPA	21 aluminium	Below detection limit (^{232}Th: <2.7)	
IFE	2 magnesium	^{212}Pb: 1.4-1.9	20-40
IFE	2 magnesium	Below detection limit (^{212}Pb: <1.4)	
NRPA	3 magnesium	Below detection limit (^{232}Th: <2.7)	

Table 5. Results of neutron activation analyses of aluminium and magnesium samples.

Laboratory	Samples	^{238}U		^{232}Th	
		ppm	Bq/kg	ppm	Bq/kg
IFE	2 aluminium	0.8-3.5	10.0-43.5	0.7	2.8
IFE	1 magnesium	0.5	6.2	0.7	2.8

4.2.2 Results from beta measurements

Some steel and aluminium samples were also measured in a GM counter. No activity was found in the steel sample and 0.3-0.5 ppm uranium was found in the aluminium samples. The uranium concentration in the aluminium samples falls in the normal order of magnitude of uranium in aluminium [24].

4.2.3 Results from neutron activation analyses

Table 5 shows results from neutron activation analyses of a few aluminium and magnesium samples. Only natural occurring uranium and thorium were found in the samples.

4.3 Discussion and conclusions

Measurements of the radioactivity in metal samples were performed at laboratories in the Nordic countries. The samples were received from steel, aluminium and magnesium producers. No radioactivity or radioactivity levels close to the detection limits were found in the steel samples. Very low activities from the naturally occurring uranium and thorium series radionuclides were found in some of the aluminium and magnesium samples.

Most samples were analysed using gamma spectrometric equipment. However, it is not a simple task to perform low-level gamma spectrometric measurements, especially with metal samples, due to heavy self-absorption of the gamma rays in the sample. This self-absorption sets a limit to the useful sample size. As the level of radioactivity in commercial metal products is generally low and close to the limit of detection, the background characteristics of the gamma spectrometer systems are very important. The background levels of the spectrometer systems at different laboratories differ.

It was only possible to analyse a limited number of samples in this study, since the measurements are very time-consuming. Therefore, it could be of interest to perform measurements of more samples both from the same and also from other metal producers, possibly also in other countries.

It can be stated that this study has found no indication of elevated radioactive contamination due to the recycling of steel, aluminium or magnesium metals. It could be of interest to repeat a similar study in the future to see how the contamination status evolves.

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Appendix 1: Acronyms

Abbreviation	**Explanation**
AFA	Avfallsprogram inom NKS (Waste programme within NKS, 1994-1997)
ALI	Annual Limit on Intake
Bq	Becquerel
CLAB	Centrallager för använt bränsle (Central Interim Storage Facility for Spent Nuclear Fuel, Sweden)
DiP	Decision in Principle
DKK	Danish currency (kroner)
DR3	Research reactor at Risø
EC	European Commission
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
Geislavarnir	Geislavarnir ríkisins (Icelandic Radiation Protection Institute)
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IFE	Institutt for energiteknikk (Institute for Energy Technology)
ILW	Intermediate Level Waste
IVO	Imatran Voima Oy, Finland
KAN	Nuclear safety and waste management research programme, NKS 1990-1993

KLDRA	Kombinert lager og deponi for lav- och middels radioaktivt avfall (Combined disposal and storage facility for radioactive waste in Norway)
LLW	Low Level Waste
LSA	Low Specific Activity
NIRH	National Institute of Radiation Hygiene in Denmark (SIS)
NKS	Nordisk kärnsäkerhetsforskning (Nordic Nuclear Safety Research)
NORM	Naturally Occurring Radioactive Materials
NPP	Nuclear Power Plant
R2	Test reactor at Studsvik
SFL	Slutförvar för långlivat avfall (Final repository for Long-Lived Waste, Sweden)
SFR	Slutförvar för reaktoravfall (Final repository for Radioactive Operational Waste, Sweden)
SIS	Statens institut for strålehygiejne (National Institute of Radiation Hygiene, Denmark)
SKB	Svensk kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Co.)
SKI	Statens kärnkraftinspektion (Swedish Nuclear Power Inspectorate)
SOS	Säkerhet och Strålskydd (Safety and radiation protection programme within NKS, 1998-2001)
SSI	Statens strålskyddsinstitut (Swedish Radiation Protection Authority)
STUK	Säteilyturvakeskus (Radiation and Nuclear Safety Authority, Finland) Strålsäkerhetscentralen
VTT	Valtion teknillinen tutkimuskeskus

Appendix 2: Participants

The table below shows the main project participants. Many other persons have participated in the project. This applies particularly to the theme meeting within the SOS-3.1 subproject.

Participants		**SOS-3.1**				**SOS-3.2**				**SOS-3.3**			
		98	**99**	**00**	**01**	**98**	**99**	**00**	**01**	**98**	**99**	**00**	**01**
Denmark													
Mette Øhlen-schlæger	SIS									X	X	X	X
Knud Brodersen	Risø	X	X	X	X	X	X	X	X	X	X	X	X
Steen Carugati	Risø	X	X	X	X	X	X	X	X	X	X	X	X
Sven Nielsen	Risø									X	X	X	X
Anne Sørensen	Risø												X
Finland													
Esko Ruokola	STUK					X	X	X	X	X	X	X	X
Maija Lipponen	VTT									X	X	X	X
Ronnie Olander	Posiva	X	X	X									
Antero Tiitta	VTT									X	X	X	X
Seppo Vuori	VTT		X	X	X								
Iceland													
Thora Johnsdottir	Geslavarnir									X	X		
Sigurður Emil Pálsson	Geslavarnir			X	X							X	X
Þóroddur Þóroddsson	Skipulag	X	X	X	X								

Norway													
Tonje Sekse	NRPA	X	X	X	X	X	X	X	X	X	X	X	X
Malgorzata Sneve	NRPA	X	X	X	X	X	X	X	X	X	X	X	X
Steinar Backe	IFE	X	X	X	X	X	X	X	X	X	X	X	X
Kristin Fure	IFE									X	X	X	X
Tore Ramsøy	IFE	X	X	X	X	X	X	X	X	X	X	X	X
Sweden													
John-Christer Lindhé	SSI										X	X	X
Åsa Wiklund	SSI									X	X		
Shankar Menon	Menon Consulting										X		
Karin Brodén	Studsvik	X	X	X	X	X	X	X	X	X	X	X	X
Yvonne Sandell	Studsvik									X	X	X	X

Appendix 3: Financing

Financing of the studies within SOS-3 including the preproject.

Country	**Participation organisations**	**NKS-financing**	**National financing**	
		DKK 000	**Financier**	**DKK 000**
Denmark	Risø, SIS	400	Risø, SIS	400
Finland	VTT, Posiva	415	VTT, Posiva	415
Iceland	Geislavarnir, Skipulag	225	Geislavarnir	225
Norway	NRPA, IFE	422	NRPA, IFE	422
Sweden	Studsvik, SSI, SKI, SKB	847	SSI, SKI, SKB	1780
Joint		311		0
Total		2620		3242

Title	Safety and Radiation Protection in Waste Management. Final Report of the Nordic Nuclear Safety Research Project SOS-3.
Author(s)	Karin Brodén et al
Affiliation(s)	Studsvik RadWaste AB, Sweden
ISBN	87-7893-117-7
Date	December 2001
Project	NKS/SOS-3
No. of pages	61
No. of tables	5
No. of illustrations	10
No. of references	24
Abstract	During 1998-2001, a project on the management of radioactive waste was carried out as part of the NKS programme. The project was called NKS/SOS-3 and was divided into three subprojects: SOS-3.1 (Environmental Impact Assessment; EIA), SOS-3.2 (Intermediate storage) and SOS-3.3 (Contamination levels in metals). SOS-3.1 included four EIA seminars on the use of EIA in the Nordic countries. The seminars were held in Norway in 1998, Denmark in 1999, Iceland in 2000 and Finland in 2001. (The last seminar was performed in co-operation with the NKS project SOS-1.) The seminars focused on experiences from EIA procedures for the disposal of radioactive waste, and other experiences from EIA processes. SOS-3.2 included a study on intermediate storage of radioactive waste packages in the Nordic countries. An overview of experiences was compiled and recommendations were made regarding different intermediate storage options as well as control and supervision. SOS-3.3 included investigation of contamination levels in steel, aluminium and magnesium samples from smelting facilities and an overview of current practice for clearance in the Nordic countries.
Key words	Clearance, clearance levels, naturally occurring radioactive materials, radioactive waste, radioactive material, intermediate storage, waste disposal, environmental impact assessment, gamma spectrometric measurements, beta measurements, neutron activation analyses

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