Radioactive Waste Management

Status and Trends - Issue #4

February 2005

IAEA/WMDB/ST/4

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RADIOACTIVE WASTE MANAGEMENT STATUS AND TRENDS – NUMBER 4
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FOREWORD

The purpose of this report is to compile and disseminate information about the status of and trends in radioactive waste management in IAEA Member States in a timely manner. The report is suitable for radioactive waste managers and regulators, decision making organizations in both governmental and private sectors, and for IAEA Departments, in both the regular and Technical Cooperation programmes. Currently, the report is targeted at readers with a good knowledge of radioactive waste management. The plan is to have the document evolve to serve a broader audience using easy-to-understand graphical and tabular data.

For this, the fourth report in the series, contributions on a variety of topics in radioactive waste management were solicited from persons and organizations external to the IAEA. Throughout the report, submissions received from external contributors are denoted.

The preparation of this report involves (a) a meeting with a team of consultants from a variety of government and industrial organizations to compile a first draft, (b) the optional issuance of special service contracts to polish and supplement the first draft, (c) review by IAEA staff and external contributors to the report and (d) final review and approval by the Director of the Nuclear Energy and Waste Technology Division (NEFW), Nuclear Energy Department, in the IAEA.

PLEASE NOTE: Publication of this report had been targeted for September 2004. Due to unforeseen delays, publication was delayed to early 2005. In several parts of this report, notes are included that reference publications that were published during the delay period, however, the text that described these "impending" publications was not rewritten (to expedite publication).

Comments concerning the current report, suggestions for future reports, including suggestions for contributions to future reports, can be sent to the IAEA as follows:

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1 DOCUMENT OVERVIEW

This fourth issue of this report is intended for persons directly involved in radioactive waste management and regulation as well as members of the general public who are relatively familiar with the nuclear industry and/or radioactive waste management. A review process has been established to enable the systematic presentation of information and the tracking of trends. As more quantitative data become available (see Section 11), the intent of the report is provide information in both the format that appears in the current issue and, additionally, in tabular, statistical and graphical formats. As such, over time, this report should become more and more suitable as an information source for persons with a limited knowledge of the nuclear industry and/or radioactive waste management.

As stated in the first issue, the basic structure of the report was derived with the intent of developing a formal framework for the assembly of information in radioactive waste management. The objectives were:

1. to identify subject areas deemed to be of interest to Member States and the IAEA,
2. to report the status of and trends in radioactive waste management according to these subject areas, and
3. to base this reporting, to the greatest extent practicable, on quantitative data.

Objectives 1 and 2 have been met. Quantitative data are not yet available at a sufficient level to achieve objective 3. However, as can be seen throughout the report, significant progress is being made in the collection of quantitative information, for example:

- Subsection 6.3.2, "Collection and Dissemination of Radwaste Processing Information by the IAEA",
- Subsection 6.4.3, "Collection and Dissemination of Radwaste Storage Information by the IAEA" and
- Subsection 7.8, "Collection and Dissemination of Radwaste Disposal Information by the IAEA"

With regards to objective 1, the reporting structure is general enough to minimize changes from issue to issue. In addition, "topical issues", such as long term storage, are included to minimize changes in the main structure of the report. However, as developments or changes take place, the reporting structure of status and trends reports will evolve, as indicated in Table 1-1. The evolution of the structure from issue 1 to issue 3 reflects the input of subject matter experts.

Issue 3 stated, "It is anticipated that the structure will change little, if all, for issue 4". The structure has changed somewhat at the subsection level but remains unchanged at the main section level.

Table 1-1: Evolution of the Structure of the S&T Report

structure of Status and Trends report, issue #1
1. HISTORICAL PERSPECTIVE 2. NATIONAL SYSTEMS FOR RADIOACTIVE WASTE MANAGEMENT 3. THE CLASSIFICATION OF RADIOACTIVE WASTE 4. SOURCES OF RADIOACTIVE WASTE 5. RADIOACTIVE WASTE MINIMIZATION AND PROCESSING 6. RADIOACTIVE WASTE STORAGE 7. RADIOACTIVE WASTE DISPOSAL 8. THE MANAGEMENT OF RADIOACTIVE SOURCES 9. MANAGING THE CONSEQUENCES OF PAST PRACTICES 10. DATA COLLECTION AND REPORTING 11. HIGHLIGHTS OF THE AGENCY'S WORK (1999/2000) 12. ASSESSMENT OF ACHIEVEMENTS AND REMAINING CHALLENGES 13. CONTRIBUTORS TO THIS REPORT
structure of Status and Trends report, issue #2
1. DOCUMENT OVERVIEW 2. NATIONAL SYSTEMS FOR RADIOACTIVE WASTE MANAGEMENT 3. THE CLASSIFICATION OF RADIOACTIVE WASTE 4. SOURCES OF RADIOACTIVE WASTE 5. DECOMMISSIONING OF NUCLEAR FACILITIES 6. LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE MANAGEMENT 7. RADIOACTIVE WASTE STORAGE 8. RADIOACTIVE WASTE DISPOSAL 9. THE MANAGEMENT OF SPENT/DISUSED SEALED RADIOACTIVE SOURCES 10. MANAGING THE CONSEQUENCES OF PAST PRACTICES 11. DATA COLLECTION AND REPORTING 12. HIGHLIGHTS OF THE WORK OF THE IAEA AND OTHER INTERNATIONAL ORGANIZATIONS (2000 – 2001) 13. ASSESSMENT OF ACHIEVEMENTS AND CHALLENGES 14. ACRONYMS, ABBREVIATIONS, SYMBOLS & EXPRESSIONS 15. CONTRIBUTORS TO THIS REPORT
structure of Status and Trends report, issue #3
1. DOCUMENT OVERVIEW 2. NATIONAL SYSTEMS FOR RADIOACTIVE WASTE MANAGEMENT 3. THE CLASSIFICATION OF RADIOACTIVE WASTE 4. SOURCES OF RADIOACTIVE WASTE 5. DECOMMISSIONING OF NUCLEAR FACILITIES 6. PRE-DISPOSAL MANAGEMENT OF RADIOACTIVE WASTE 7. RADIOACTIVE WASTE DISPOSAL 8. EXAMPLES OF EXISTING REPOSITORIES 9. THE MANAGEMENT OF SPENT/DISUSED SEALED RADIOACTIVE SOURCES 10. MANAGING THE CONSEQUENCES OF PAST PRACTICES 11. DATA COLLECTION AND REPORTING 12. HIGHLIGHTS OF THE WORK OF THE AGENCY AND OTHER INTERNATIONAL ORGANIZATIONS IN 2002 13. ACHIEVEMENTS AND CHALLENGES 14. ACRONYMS, ABBREVIATIONS, SYMBOLS & EXPRESSIONS 15. CONTRIBUTORS AND REVIEWERS

The various Sections in the report were developed within the context of questions such as:

- What are the end points to be achieved in the identified subject areas?
- What is the current global situation with respect to reaching those end points?
- What is the basis for understanding the current situation?
- What are the gaps between the current situation and what is to be achieved?
- Are there changing directions and/or trends to achieve the end points?
- What events have lead to any changes in directions and/or trends?

Under most Section headings there is a declared purpose for the Section. In addition, there may be some general remarks explaining the breakdown of the Section into specific topic areas. The beginning of a Section may also contain a brief summary of the information presented in the previous issue of the Status and Trends report, thereby minimizing the need to refer back to the previous report. This summary may include minor repetition or paraphrasing of text from the previous issue of the report.

Each Section of the report describes a subject area in radioactive waste management where work is ongoing. Part of the Section's text will discuss the status of the subject area. In addition, questions will be addressed such as "Are there any unresolved or controversial issues?", "What noteworthy events or activities took place since the last Status and Trends report?", and "What trend(s) can be assessed?".

In one or more subject areas, there may not yet be any emerging trends, only an ongoing work programme. As an example, security has recently emerged as a key topic area within Waste Management Systems and there is currently much activity. However, until that activity has matured to the point where a clear trend has emerged, for example in the design of new storage facilities, this Status and Trends report will only be able to inform the reader of the current status of ongoing work.

Each Section may contain one or more subsections. Subsections without "Topical Issue" included in their titles are meant to cover specific subject areas that are **likely** to be discussed over a number of issues of the Status and Trends report. These are subjects with anticipated "on going" interest. Subsections with "Topical Issue" included in their titles are meant to cover subject areas that are considered "timely". These subjects **may not** be discussed in subsequent issues of the Status and Trends report (i.e., they are "newsworthy" or "sensitive" topics).

Subsections could include either "Topical Issue" or "Topical Issue – Update" in their titles. If "Update" is not included in the subsection title, the subsection introduces a new topical issue into the Status and Trends report. If "Update" is included in the subsection title, the subsection provides an update of a topical issue that was discussed in a previous issue (or issues) of the Status and Trends report. The relevant issue(s) is (are) cited within the body of the subsection.

Most Sections of this report include a list of reference documents. As additional issues are published over time, this Status and Trends report will serve as a valuable reference tool for understanding radioactive waste management in IAEA Member States.

2 NATIONAL SYSTEMS FOR RADIOACTIVE WASTE MANAGEMENT

This purpose of this Section is to provide an overview of the development of nationally based systems that are necessary for the safe and effective management of radioactive waste, at the attempts to establish consistent approaches between Member States and the issues that currently impact upon these attempts. The subject area is covered by the following subsections:

- The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [2.1],
- Scorecard for National Systems for Radioactive Waste Management,
- Ongoing Initiatives Between Member States,
- Topical Issue: Proposed European Council Directive (EURATOM) on the Implementation of National Systems, and
- Topical Issue – Update: Indicator of Sustainable Development for Radioactive Waste Management.

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

As reported in previous issues of this Status and Trends report, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) was adopted on 5 September 1997 and entered into force on 18 June 2001. The first Review Meeting of the Contracting Parties to the Joint Convention was held at IAEA headquarters from 3 to 14 November 2003 (the IAEA is the Secretariat for the Joint Convention).

The Summary Report for the Review Meeting indicated that the National Reports that were prepared by the Contracting Parties enabled them to not only take stock and to review how others were implementing the articles of the Convention, but also to share good practice [2.2]. However, it was noted that the first review under the Convention was very much a learning process and that not all National Reports contained sufficient practical information on the implementation of their [Contracting Party] programs. The Contracting Parties noted that their participation in the production and review of reports, the questions and answers exchanged and the presentations, had provided them with a unique insight into the status of spent fuel and radioactive waste management activities across the complete spectrum of programmes, from large to very small.

Table 2-1 contains excerpts from the Summary Report for the Review Meeting. These excerpts describe issues that arose from the Review Meeting. Table 2-1 indicates where the identified issues are discussed within this Status and Trends report. The table also indicates where this Status and Trends report does not address the identified issues (these are gaps that may need to be closed in future reports).

In Table 2-1, NEWMDB refers to the IAEA's Net Enabled Waste Management Database [2.3].

Table 2-1: Joint Convention Review Meeting Summary Report in Relation to this Status and Trends Report

Excerpts from the Joint Convention Review Meeting Summary Report (issues identified in the report, **bold text** indicates the main issues raised)	Sections/Subsections where issues are discussed in this Status and Trends report
…The objectives of the Convention are: i) to achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management, through the **enhancement of national measures** and international cooperation, including where appropriate, safety-related cooperation… …there were large variations reported in the status of **national plans** for the ultimate management solution of spent fuel and radioactive wastes… …While some Contracting Parties had overall solutions for the management of intermediate or high level wastes, most countries were still considering what approaches to follow and a few have not initiated this important process…	**Section 2** (*National Systems for Radioactive Waste Management*) also see: Subsection 6.3.2 Subsection 6.4.3 Subsection 7.8 Section 11
…All Contracting Parties believed that **public consultation** on radioactive waste management strategies was not only a good practice to follow, but was also essential for the development of a successful and sustainable policy …There was some discussion on policies relating to the **regulation** of radioactive waste management activities. Practices and policies differed markedly… …In some Contracting Parties, the regulation of nuclear safety and radioactive waste management was carried out by a single regulator. In others, there were different regulators for each activity… …All felt that a clear allocation of responsibilities was essential. There were some discussions on the independence of the regulator… …not all Contracting Parties have regulators who are independent of those who produce or manage radioactive waste, or their sponsoring Ministries… …Many Contracting Parties reported on the status of their policies concerning the provision of **financial assurances** for future decommissioning, long-term monitoring, and disposal… …Several Contracting Parties commented on the **resources** needed to provide effective regulation. The Contracting Parties agreed that in line with Article 20 (1) of the Convention, Governments should ensure that the regulatory bodies have adequate resources… … Many countries are experiencing difficulties in **assuring** an adequate on-going supply of **qualified staff**…. …Several Contracting Parties reported that their legislative and regulatory requirements prohibited the **importation of radioactive wastes** except for disused sealed sources or the recovery of usable materials… …The Contracting Parties agreed that for the safe and successful management of spent fuel and radioactive waste, there needed to be a clear **legal framework**; a strong and independent **regulatory function**; competent licensees or operators; clear lines of responsibility and accountability; **public involvement** in the decision making process; **adequate financial provisions**; clear, integrated, plans on how spent fuel and radioactive waste will be managed to ensure continued safety into the future, and as this could be for decades, to avoid creating a legacy situation that would impose undue burden on future generations… …Many Contracting Parties reported **planned activities that will improve safety** of the management of spent fuel or the safety of the management of radioactive wastes…	See issue #3 of this Status and Trends report, Subsection 2.3, "*Topical Issue: Scorecard for the Implementation of National Systems for Radioactive Waste Management*" [2.4] also see Page 18, "*Scorecard for National Systems for Radioactive Waste Management*"

Excerpts from the Joint Convention Review Meeting Summary Report (issues identified in the report, **bold text** indicates the main issues raised)	Sections/Subsections where issues are discussed in this Status and Trends report
…Contracting Parties use different criteria for **classifying radioactive waste**……there were several comments on **clearance levels** for the disposal or reuse of materials with very low levels of radioactive contamination. It was agreed that renewed efforts should be made to get international consensus on this issue… … Discussion of the issue of low level waste management led to several comments on **clearance levels** and practices, as highlighted above. Some Contracting Parties have clearly defined clearance levels based on radiological criteria, with policy statements that material below those levels can be recycled or disposed of with non-radioactive wastes. Other countries have, in addition to general criteria, a case-by-case approach to clearing radioactive wastes. There were questions on the criteria for disposal and **it was agreed that further guidance could be developed as part of the IAEA Safety Standards programme**…	**Section 3** (*The Classification of Radioactive Waste*) also see Subsection 4.3
…there were several comments on the **scope of the Convention** in relation to uranium mining and milling wastes and wastes from the use of other naturally occurring radioactive materials. Some Contracting Parties had included these in their reports, others had not… …There was no common approach to managing uranium mining and milling wastes. In some Contracting Parties, these wastes are in the legacy category…	**Section 4** (*Sources of Radioactive Waste*)
…there was a growing recognition of the need for the development and implementation of **integrated decommissioning and radioactive waste management plans**… …Several Contracting Parties reported on progress in this area and regarded such plans as crucial to the delivery of the successful decommissioning of nuclear sites and making them safe for future generations… … There was some confusion over what was meant by decommissioning in the context of the Convention. Some Contracting Parties thought decommissioning only applied to nuclear power plants, whilst others clearly applied the concept to all nuclear installations and nuclear facilities. It was agreed that at the next meeting **National Reports should address the decommissioning of all nuclear installations and facilities** as defined in the Convention… … Contracting Parties now engaged in decommissioning nuclear facilities agreed that successful decommissioning depended upon a number of key factors… The first was the need to make adequate financial provision… …The second was the need to ensure that **adequate records** were kept by the operators, of inventories and activities, throughout the operating period of the facility.…	**Section 5** (*Decommissioning of Nuclear Facilities*) The decommissioning section of this status and trends report has included, over its various issues, discussions of the decommissioning of various types of nuclear facilities, not just nuclear power plants.
…there was some discussion on how to manage **mixed wastes**, i.e. radioactive and other hazardous materials. It was suggested that this would be a suitable area for additional guidance… …there was some discussion on the criteria for the design life of facilities for the storage of spent fuel and radioactive waste, pending decisions on future management including disposal… …there were several comments made on the **long term storage** of spent fuel… … Contracting Parties also felt that the long term storage of spent fuel or radioactive waste could impose an undue burden on future generations… … Some Contracting Parties intend to continue to store radioactive waste for prolonged periods of time, with regulatory control being maintained over the facilities as appropriate. Discussions concerning perpetual institutional control concluded that as one component of a multi function system of control it could be acceptable and not considered as an undue burden on future	**Section 6** (*Predisposal Management of Radioactive Waste*) also see Subsection 2.5 (Topical Issue – Update: Indicator of Sustainable Development for Radioactive Waste Management) regarding "**safe storage**"

Excerpts from the Joint Convention Review Meeting Summary Report (issues identified in the report, **bold text** indicates the main issues raised)	Sections/Subsections where issues are discussed in this Status and Trends report
generations… … The general policy in all Contracting Parties is to **minimise the production of radioactive waste**, although many Contracting Parties have significant radioactive waste legacies to deal with… …Several Contracting Parties commented on the conditioning of radioactive waste for either storage or disposal. All Contracting Parties agreed that for **safe storage**, radioactive waste had to be conditioned to a high quality standard to ensure safety and stability during storage, and retrieval…	
… There was a discussion on issues of the disposal of spent fuel in countries with only research reactors or small nuclear power programmes and the long-term management of radioactive waste in small countries without nuclear power programs. The possibility of a solution based upon **regional disposal facilities** was discussed. … … Although disposal, by definition, excludes the intention of retrieval, there is an increasing interest in the development of radioactive waste repositories which will **enable retrieval** of wastes, at least to a limited degree or for a limited period of time. …	**Section 7** (*Radioactive Waste Disposal*) and **Section 8** (*Examples of Existing Repositories*)
…Contracting Parties reported a wide range of approaches to the **management of disused sealed sources**… …This whole area of the management of disused sealed sources would benefit from additional detail in the National Reports for the next Review Meeting…	**Section 9** (*The Management of Spent/Disused Sealed Radioactive Sources*)
…Several countries reported on the problems associated with remedying **legacy situations** resulting from practices that were in existence before today's knowledge, societal expectations and regulatory controls existed…	**Section 10** (*Managing the Consequences of Past Practices*)
…One Contracting Party declared its **military wastes** to be within the scope of the Convention… … In the case of military wastes, it was agreed that wastes within military programs are not within the scope of the Convention, but for wastes arising from military programs and transferred to civil programs, the Convention applies… …Contracting Parties generally reported adequate methods of maintaining **inventories of radioactive wastes** and spent fuel, with some having well-developed electronic data bases that were regarded as good practices. Some Contracting Parties, had arrangements for **accounting for disused sealed sources** that were not as well developed and it was agreed that more attention should be focused in this area and other radioactive wastes from small users. There were examples of good practice and the Contracting Parties agreed that more should be done to help small users to acquire the necessary knowledge and skills.… … Some Contracting Parties regarded the **detailed locations** and local inventories of spent fuel and radioactive wastes as information that is **no longer in the public domain because of security considerations**… … Contracting Parties commented upon the balance between the description of institutional measures and the **reporting of practical activities** in some National reports. There was recognition that, as this was the first time that reports had been produced under the Convention, there would be an emphasis on explaining the regulatory and institutional frameworks… … Contracting Parties agreed that National Reports **for the next Review Meeting should be more focused on the practical activities being carried out to meet the objectives**, and the implementation of the obligations of the	**Section 11** (Data Collection and Reporting) The NEWMDB: • allows Member States to declare defense/military waste • allows Member States to show or hide facility locations • serves as a source of "**practical activities**" information that could be used for National Reports of Contracting Parties to the Joint Convention • serves as a valuable mechanism for "**international information exchange**" about national waste management programmes and waste inventories This Status and Trends report serves as a timely source of information on the status of and the trends in radioactive waste management. The IAEA intends to collect and disseminate information with the NEWMDB on an annual basis.

Excerpts from the Joint Convention Review Meeting Summary Report (issues identified in the report, **bold text** indicates the main issues raised)	Sections/Subsections where issues are discussed in this Status and Trends report
Convention… …All Contracting Parties acknowledged the benefit from the **international information exchange**, as an important opportunity to learn from each other, especially in relation to good practice and to areas of improvement… … The Contracting Parties look forward to **meeting again in three years time to share information on the progress they are making** and further improve their safe management of spent fuel and radioactive waste.…	
…Some Contracting Parties reported on the considerable benefit that was derived from involvement in international programmes such as **peer reviews carried out by international organisations** such as the IAEA and the OECD/NEA[1]…	**Section 12** (*Highlights of the Work of the IAEA and Other International Organizations in 2003*)
…It was noticeable that with the exception of a few Contracting Parties, there was little discussion on national practices concerning radioactive **discharges to the environment**. Contracting Parties' National Reports for the next Review Meeting should give more coverage of this topic…	Currently, the discharge of waste to the environment is not addressed in this Status and Trends report.
… of the reported **transboundary shipments**, concerned spent nuclear fuel. However, the number of transboundary shipments of radioactive waste was likely to increase as waste from reprocessing was progressively returned to customers.…	Currently, the transboundary movement of waste is not addressed in this Status and Trends report.
…there was some discussion on the development and use of effective **safety assessment tools** for radioactive waste facilities. It was acknowledged that for some applications the tools available were adequate but for others, there was scope for further development, possibly through improving the IAEA Safety Standards…	Currently, safety assessment tools are not addressed in this Status and Trends report.
…Contracting Parties reported on the degree of planning to respond to **emergency situations**…	Currently, emergency preparedness is not addressed in this Status and Trends report.
…Where disposal facilities for intermediate or high level wastes were not available, **Contracting Parties treated and stored waste in a wide variety of facilities**. This highlighted the **need to develop international standards** for such activities and facilities to enable consistent design, operation and regulation…	Currently, the development of international safety standards is not addressed in this Status and Trends report.

1 Organization of Economic and Development and Cooperation / Nuclear Energy Agency

2.2 Scorecard for National Systems for Radioactive Waste Management

Subsection 11.1 of the second issue of this Status and Trends report described a scorecard to measure progress towards the implementation of national systems for radioactive waste management in IAEA Member States. The compilation of data in support of the scorecard uses the IAEA's Net Enabled Waste Management Database (NEWMDB).

Subsection 2.3 of the third issue of this Status and Trends report elaborated upon the scorecard and indicated that, due to a low Member State participation in the first two data collection cycles, too few data had been collected to date to draw broad conclusions. The third issue referenced the initial scorecard results [2.5].

NEWMDB version II was implemented in 2004 and a third data collection was held March to July. A "query tool" was implemented to allow Public Users to interactively view scorecard results since IAEA Member States can now add or update submissions to the database at any time, not only during formal data collection cycles. Instructions for registering as a Public User, for accessing NEWMDB reports and for executing interactive queries can be accessed at the following Internet address:

> http://www-newmdb.iaea.org/help/instructions2003.pdf
> To view scorecard reports, registered Public Users access the Public Area, click on the Tools tab, click on the Statistics link (in the left hand side of the page under TOOLS), select Policies Report from the "—select query—" list and click the REFRESH button.

The reports contain information relevant to various issues identified in the first Review Meeting of the Contacting Parties to the Joint Convention (see Table 2-1). Examples, based on query results as of 25 November 2004, are shown in Table 2-2.

Table 2-2: Joint Convention Review Meeting Issues Compared with the Scorecard on National Systems for Radioactive Waste Management

issue identified in the Joint Convention Review Meeting …All Contracting Parties believed that **public consultation** on radioactive waste management strategies was not only a good practice to follow, but was also essential for the development of a successful and sustainable policy… score card result			
Has your Country implemented formal mechanisms for disseminating information to the public and for public consultation?			
Yes: 46.3%	Partially: 39.0%	No: 14.6%	# of responses: 41
issue identified in the Joint Convention Review Meeting …Many Contracting Parties reported on the status of their policies concerning the provision of **financial assurances** for future decommissioning, long-term monitoring, and disposal… score card result			
Has your Country implemented a funding structure and the allocation of resources that are essential for radioactive waste management?			
Yes: 52.4%	Partially: 28.6%	No: 19.0%	# of responses: 42
issue identified in the Joint Convention Review Meeting …Several Contracting Parties reported that their legislative and regulatory requirements prohibited the **importation of radioactive wastes** except for disused sealed sources or the recovery of usable materials… score card result			
Does your Country have laws or Regulations restricting either the import or export of radioactive waste (excluding spent fuel)?			
Yes: 78.6%	No: 21.4%	# of responses: 42	

The above indicates that the NEWMDB can serve as a valuable source of information about the status of and trends in the implementation of national systems for radioactive waste management. However, care must be exercised that information provided to the NEWDMB does not conflict with information provided in National Reports of Contracting Parties to the Joint Convention. Additionally, increased participation by Member States in submitting information to the NEWMDB is needed to achieve better statistics on the implementation of national systems in Member States.

2.3 Ongoing Initiatives Between Member States

Previous issues of this Status and Trends report described ongoing initiatives between IAEA Member States in the field of radioactive waste management. The second issue described European Union (EU) programmes to assist non-EU countries. The third issue described activities of the Forum for Nuclear Cooperation in Asia.

This fourth issue of the Status and Trends report discusses multinational/regional waste management facilities (see Subsection 7.2), activities of the European Commission (EC, see Subsection 12.3) and activities of the Nuclear Energy Agency (NEA) of the Organization of Economic Cooperation and Development (OECD, see Subsection 12.4). In addition, this fourth issue provides an overview of the "International Association for Environmentally Safe Disposal of Radioactive Materials" (EDRAM, see Subsection 12.6).

A significant event in 2003 in the area of international cooperation was the inauguration of the World Nuclear University (WNU, http://www.world-nuclear-university.org). While the WNU's mission covers the whole nuclear education spectrum, it includes radioactive waste management as a component.

2.4 Topical Issue: Proposed European Council Directive (EURATOM) on the Implementation of National Systems

In early 2003, the European Commission (EC) set out a proposal for a Council Directive (EURATOM) on the management of spent nuclear fuel and radioactive waste [2.6]. The thrust of the proposal is that it has no intention to duplicate standards related to spent fuel and radioactive waste management that are currently in place within EU Member States. The proposal uses the Joint Convention as a basis and highlights the need to harmonize with its requirements. However, the EC is aware that existing standards and practices are not uniform within the EU and that the imminent enlargement of the EU could bring with it some additional problems. While harmonization across the enlarging community could be seen as an eventual objective, the most important issue at this moment is the lack of progress in some Member States on the long term management of spent fuel and radioactive waste. This is especially the case for high level and long lived waste. The EC is, therefore, proposing that each Member State adopt a programme for the safe, long term management of all the wastes under its control and to report on these at regular intervals. The reports would then be reviewed by all other Member States.

On the specific issue of the disposal of spent fuel and radioactive waste, the proposed Directive makes it clear that long term storage of spent fuel and waste is not a safe and sustainable option and puts the emphasis on the development of geological disposal, in particular "where there is no suitable alternative". However, technologies for waste minimization and alternatives to geological disposal should still be investigated. The Directive puts significant emphasis on more and better coordinated research in the area of radioactive waste management, including the search for common solutions. The proposed Directive also clearly states that the decision making processes adopted by EU Member States regarding such issues must be transparent and make appropriate use of public consultation.

2.5 Topical Issue – Update: Indicator of Sustainable Development for Radioactive Waste Management

As discussed in the first three issues of this Status and Trends report, as a follow up to the United Nation's Conference on Environment and Development (UNCED) in 1992, the UN's Department of Economic and Social Affairs (DESA) invited the IAEA to develop one or more Indicators of Sustainable Development (ISD) for the management of radioactive waste (RW). Responsibility for this task was given to the IAEA's Division of Nuclear Fuel Cycle and Waste Technology (NEFW) within the Department of Nuclear Energy. A single ISD-RW was developed by NEFW.

The ISD-RW:

- recognizes the shortcomings of a purely volume based approach for an indicator,
- is a single, dimensionless indicator that includes a consideration of waste volumes in its derivation, and
- provides a measure of both the current status of radioactive waste management at any point in time and the progress made over time towards the sustainability of radioactive waste management. This measure can be at the national level for a country or it can be at sectoral levels, such as nuclear applications (e.g., medical and industrial applications).

DESA accepted the ISD-RW into its list of Core Indicators in November 2002 [2.7].

Sustainability is the point at which the amount of radioactive waste awaiting disposal is not increasing, the waste is in the final form required for disposal and it is being safely stored. Note, since currently there is an international debate about whether or not disposal is the endpoint for waste management (some have proposed alternatives such as indefinite storage), the use of the term disposal in the context of the ISD-RW implies any internationally acknowledged alternative to disposal.

The ISD-RW is based upon two factors that are applied to EACH of the waste classes used and reported by a country. Each factor has 4 states that indicate progress by way of milestones. The use of these two factors results in the ISD-RW being expressed as a dimensionless number between 0 and 100 with 0 being the least sustainable condition and 100 being the most sustainable condition.

As described in a guidance document [2.8], the two factors were derived to reflect the management of waste and to cover the major activities of waste processing (see Subsection 6.3) coupled with the final endpoint of the waste. The factors are presented as independent but are linked. The guidance document also states "*A conclusion from the September 2002 consultancy was that countries that prepare NEWMDB [Net Enabled Waste Management Database] submissions should be able to calculate the ISD-RW based on those submissions plus supplemental information that is likely to be available (such as qualitative information that is needed to answer the guidance questions).*".

Based on the conclusion above, an "ISD-RW calculator" was added to the Public Area of the NEWMDB [2.3] in March 2004 – see Figure 2-1. Instructions for registering as a Public User can be accessed at the following Internet address:

> http://www-newmdb.iaea.org/help/instructions2003.pdf
> To access the ISD-RW calculator, registered Public Users access the Public Area, click on the Tools tab and click on the ISD-RW Calc. link (in the left hand side of the page under TOOLS).

The calculator was added to the Public Area of the NEWMDB to raise awareness of the ISD-RW and to remove any spectre that its use is limited to "Authorized Users" of the NEWMDB. Since use of the ISD-RW is for national purposes, not for IAEA use, the results of calculations are NOT saved in the NEWMDB or in any IAEA information system. Instead, they are saved in "cookies" on the personal computer of the person performing calculations.

In September 2004, a consultants' meeting was held at IAEA headquarters in Vienna, Austria. Consultants had used the ISD-RW calculator to assess the sustainability of radioactive waste management in their own countries (because use of the ISD-RW is for national purposes, the results of the assessments were not requested by or given to the IAEA).

The consultants recommended:

- a minor change to the logic diagram for the "form factor", and

- improvements to the guidance to:
  - facilitate use of the ISD-RW by persons whose 1st language is not English
  - add mass as a means of assessing changes in quantities of waste (currently only volume is used and spent nuclear fuel that is declared to be radioactive waste is typically cited by mass, not volume).

In September 2004, a request was sent to DESA seeking permission to accept and post the updated guidance for the ISD-RW on its web site. Permission was obtained in early October 2004. The guidance document for the ISD-RW was updated, submitted to DESA, and posted on the DESA website. In addition, the ISD-RW calculator and its associated on line documentation within the NEWMDB were updated.

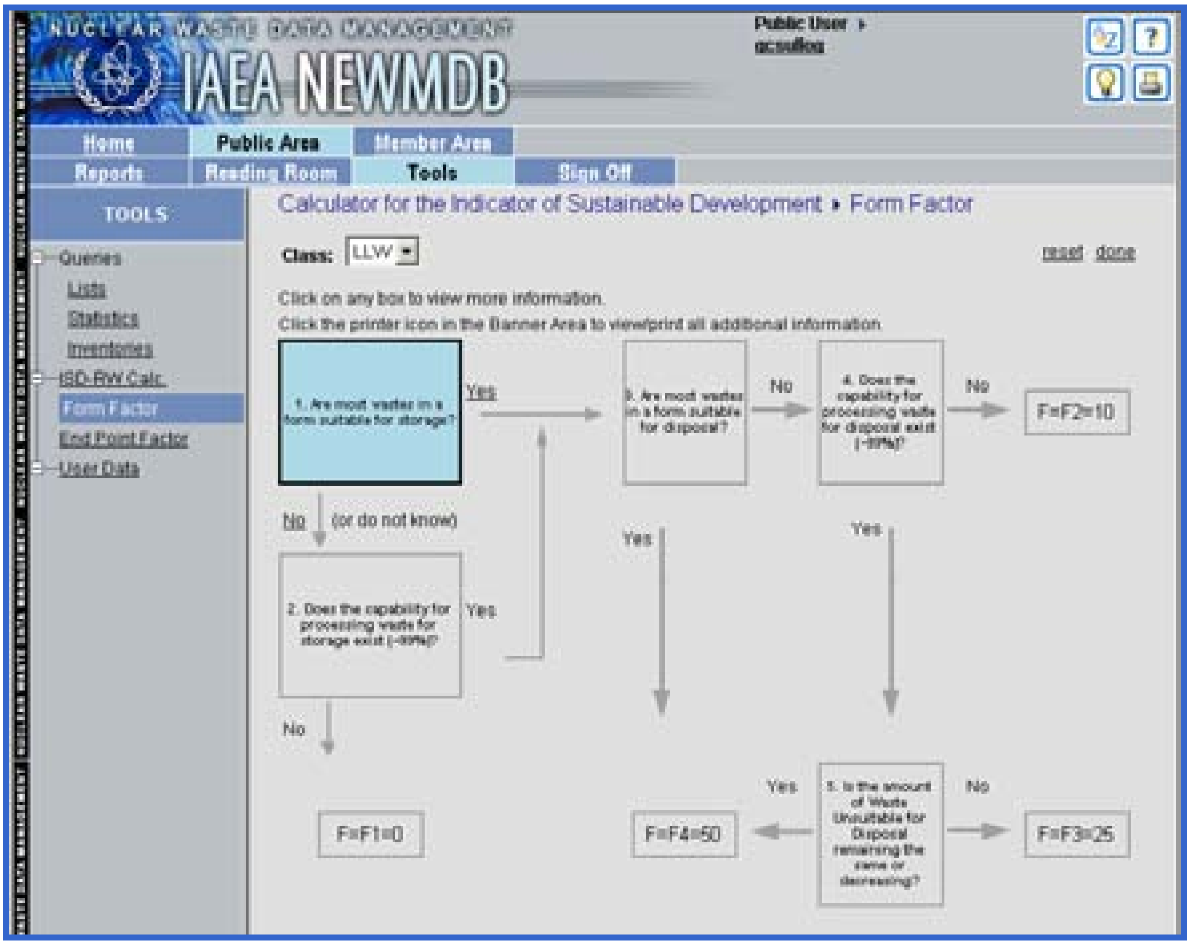

Figure 2-1: Calculator for the Indicator of Sustainable Development for Radioactive Waste Management (ISD-RW)

<u>References for Section 2</u>

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http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/isd-ms2001economicB.htm#radioactivewaste

2.8 *ibid* (a link to the guidance document is provided in Reference [2.7])

3 THE CLASSIFICATION OF RADIOACTIVE WASTE

The purpose of this Section is to raise international awareness of a number of issues related to the classification of radioactive waste. These issues are discussed further in two subsections:

- Exclusion, Exemption and Clearance (Subsection 3.1), and
- Radioactive Waste Classification within the IAEA's Common Framework Initiative (Subsection 3.2).

Waste classification was discussed in the first three issues of this Status and Trends report as follows:

first issue: non-radiological hazards, waste versus resource classification,

second issue: non-radiological hazards, waste classification at the national and international levels, classification of spent fuel,

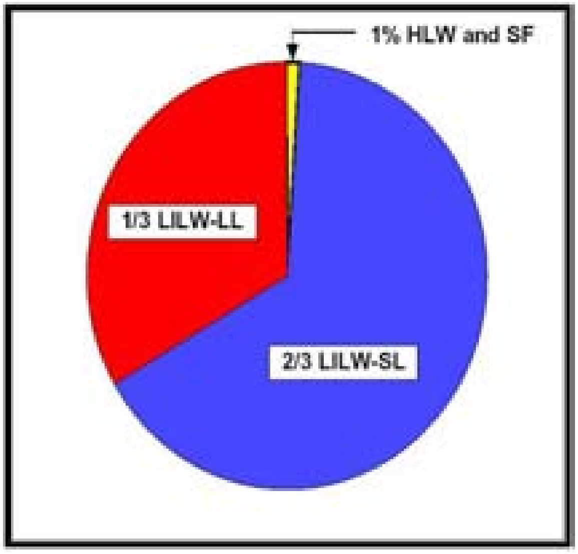
third issue: waste classification at the national and international levels, and

first three issues: exclusion, exemption and clearance.

The main issues identified from previous examinations of radioactive waste classification are:

- Radioactive waste classification varies widely at the national level.
- Several assessments of waste classification were carried out [3.1 to 3.3] - they indicated that harmonization was needed (Note: These recommendations were made a number of years after the IAEA's proposal for a common radioactive waste classification scheme. [3.4]).
- The stated objective of the IAEA's proposed common classification scheme was "*to recommend a method for deriving a classification system and to suggest a general system for classifying radioactive waste that will facilitate communication and information exchange among Member States*". The IAEA's recommended scheme was not meant to be adopted for use as a complete scheme – it was only meant to serve as a tool for developing a complete scheme and for information exchange if used "as is".
- A stated purpose of the IAEA's proposed common classification scheme was to "*specify boundaries in a general system for classifying waste, especially in the assignment of boundaries to radioactive waste clas*ses". An assessment of this purpose [3.5] indicated that the existing boundary conditions are ambiguous. Many Member State contacts for the NEWMDB found the "*methods by which boundaries can be derived*" inadequate or confusing.
- The proposed common classification scheme objective to "*eliminate some of the ambiguity that now exists in classification schemes for radioactive wastes*" was only partially achieved - ambiguity regarding the classification of radioactive waste still exists in many IAEA Member States.

Figure 3-1 visually illustrates the issue of widely varying waste classification schemes at the national level. Two different overviews of the distribution of waste by similar waste classification schemes are shown. The issue at hand is not which distribution is "right" but that the distributions are significantly different.



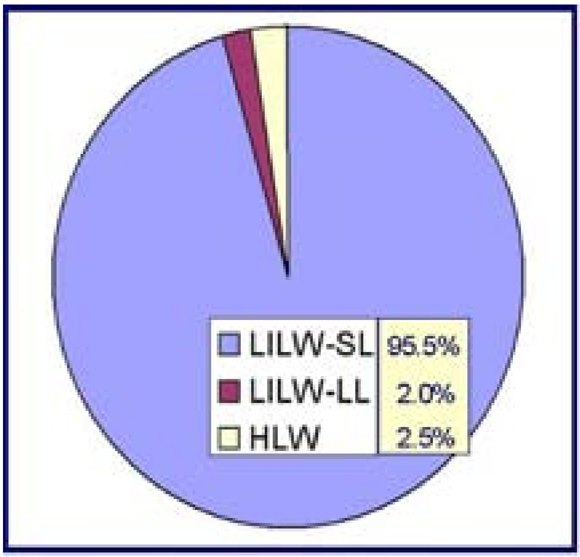


Figure 3-1: Distribution of Waste by Volume

The image on the left, which appears in the first two issues of this Status and Trends report, indicates the estimated distribution of waste, by volume, in the European Union when reported according to a common classification scheme that is based on the IAEA's proposed common classification scheme [3.6].

The image on the right indicates the estimated distribution of waste, by volume, in the 36 IAEA Member States that made submissions to the NEWMDB [3.7]. While Member States reported waste inventories according to their own waste classification schemes, they also defined "waste class matrices" that related their waste classes to the IAEA's proposed common classification scheme. The IAEA then transposed national data into inventories reported according to the common classification scheme and rolled them up into a consolidated waste inventory.

In the case of the European Commission report, all EU Member States had agreed to supply figures corresponding to the classification scheme for reporting published in the Commission's Recommendation of September 1999 [3.6]. Though this scheme had been agreed following lengthy discussions with technical representatives from Member States, no additional guidance was provided at the time the request for data was issued. Detailed guidance was provided to IAEA Member States on how to relate their waste classification schemes to the IAEA's common scheme when completing waste class matrices in the NEWMDB. Whether or not the difference in the level of guidance had an impact upon the results obtained has not been assessed. The results highlight the significance of the statement that the "*lack of full and effective cooperation between departments and institutions both at the national and international levels responsible for data collection.. ..often leads to inefficient information management due to duplication of surveys, inconsistent methodologies and inefficient use of information*" [3.8].

Subsection 3.2 describes the IAEA's "way forward" on this issue.

3.1 Exclusion, Exemption and Clearance

Note: Due to unforeseen circumstances, the publication of this Status and Trends report was delayed for several months after the "final draft" was written. During the delay period, the document "Application of the Concepts of Exclusion, Exemption and Clearance Safety Guide", Safety Standards Series No. RS-G-1.7, was published (September 2004). It can be downloaded free of charge from the IAEA via the following link:

http://www-pub.iaea.org/MTCD/publications/PDF/Pub1202_web.pdf

For several years, work has been ongoing under the auspices of the IAEA's Waste Safety and Radiation Safety Standards Committees to complete guidance on this topic. The most recent efforts were prompted by a resolution of the IAEA's General Conference in 2000, which requested the Secretariat to develop radiological criteria for long lived radionuclides in commodities.

After a number of "false starts" in which, among other activities, attempts were made to define all embracing "scoping levels" that would establish a lower bound for radiological protection regulations below which they would not apply, it was decided to utilize existing concepts within the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) [3.9].

It was recognized that in order to be acceptable to all countries, guidance should not be written in a country-specific way. After extensive consultation with Member States, including those that had great difficulties to use previous versions of the document within their regulatory framework, it was agreed to draft the guidance in a more flexible way. This entailed, in a sense, a departure from the prevailing interpretations of the text of the BSS.

One of the consequences of this approach is that the distinction between raw materials having unmodified concentrations of radionuclides and materials where the concentrations have been modified is taken away, because it introduced an unnecessary complication (see Subsection 4.2).

The problem that has arisen here may stem from the examples of exclusion given in the BSS, which include a reference to 'unmodified concentrations of radionuclides in most raw materials'. However, it should be noted that this is just an example and is not intended to be exhaustive. The key concept in relation to exclusion is contained in the phrase 'essentially unamenable to control through the requirements of the Standards', which should be taken to mean that regulatory controls are unwarranted because the expenditure in social resources in applying controls would exceed any benefit arising from their implementation. It is not relevant whether radionuclide concentrations in materials have been modified or not.

The other consequence is the recognition that the restriction of the concept of exclusion to radionuclides of natural origin is proposed to be lifted.

There is essentially universal support for using the dose criterion for exemption from the BSS – 'of the order of 10 μSv or less in a year' – for exemption or clearance of materials containing radionuclides of artificial origin. Exposure scenarios have been modelled and activity concentrations assessed on the basis of this criterion. An additional criterion of less than 1mSv per year for low probability values of model parameters has also been employed.

However, this procedure would be simply impractical for radionuclides of natural origin. Consequently, the concept of exclusion has been used to derive reference levels for radionuclides of natural origin – the criterion being an interpretation of 'essentially unamenable to control' along the lines explained above. The process adopted was to review activity concentrations in naturally occurring materials around the world and to set a reference level on the basis of informed judgement. The levels have been selected from the upper end of the distribution of activity concentrations.

Thus, the radionuclide concentration values for radionuclides of natural origin have been derived from criteria based on the concept of exclusion and interpretation of the phrase 'essentially unamenable to control', while the values for radionuclides of artificial origin have been derived from criteria based on the concept of exemption as expressed in the BSS. The result is a single set of numbers: each radionuclide, whether of natural or artificial origin, has only one activity concentration reference level associated with it.

The method of derivation, that is the strategy adopted to establish a single set of numbers that mark a boundary, does not necessarily determine the approach to be used in implementation of the values. The choice of mechanism for implementing this boundary – whether through exclusion or through exemption – can be left to the national authorities and may well depend on the national legislative culture that exists within countries.

Work has now proceeded to a stage that both the Radiation Safety Standards Committee (RASSC) and the Waste Safety Standards Committee (WASSC, see Subsection 12.1.2) in a joint session during their regular meetings in March 2004 have reviewed the draft text with the modifications as described above. While a number of Committee members expressed varying concerns, a consensus was reached in a spirit of compromise and it was agreed that the draft document should be submitted to the Commission on Safety Series (CSS) for endorsement for publication, subject to additional changes made at the meeting.

The main changes made to the document during the discussions can be summarized as follows:

- A generic exclusion/exemption level for natural radionuclides is set at 1 Bq/g for all radionuclides except K-40. For K-40 a value of 10 Bq/g applies.
- It was agreed to include a statement in the document to the effect that there are situations (such as the use of some building materials containing natural radionuclides) where exposures from material with activity concentrations below the agreed exclusion/exemption values would necessitate consideration by the regulatory body.
- Also some changes to the paragraphs dealing with trade were accepted, in order to clarify that ensuring compliance does not imply systematic monitoring.
- Comments made to the supporting Safety Report containing all parameters, values and scenarios used will be reviewed by the Secretariat jointly with the two Chairmen of the Committees.

It was further agreed that:

- The levels in the document can also be used for clearance of moderate to bulk amounts of material.
- The Safety Report will be published at the same time as the Safety Guide.

3.2 Topical Issue: Radioactive Waste Classification within the IAEA's Common Framework Initiative

The International Conference on Safety of Radioactive Waste Management, held in Córdoba, Spain (2000) [3.10] identified a number of issues relevant to the IAEA's Waste Safety Programme. It was concluded that the ongoing activities of the IAEA were largely addressing these issues, but a number of actions were proposed aimed at strengthening and focusing the work to ensure the issues were adequately covered.

One particular issue identified was that while Safety Standards on near surface disposal had been issued, the scope and some of the criteria underlying these standards are not applicable to waste containing long lived radionuclides. This is particularly the case for waste from the mining and processing of radioactive ores and minerals and for waste from the remediation of areas contaminated with long lived radionuclides (pp 264-267 of the Córdoba Conference Proceedings focused on international "inconsistencies" for the disposal of long lived waste at or near surface). Another concern identified was the disposal of spent radioactive sources in boreholes, which does not fall clearly into the category of either near surface or geological disposal.

It was concluded that a need existed to establish a common framework for disposal principles that would account for all the different types of radioactive waste. A document was subsequently prepared setting out proposals for a common framework and its application.

During 2002, comments were received on the proposals document from the Subgroup on Principles and Criteria of the Waste Safety Standards Committee (see Subsection 12.1.2). A particular issue raised was the optimum approach for the disposal of non-heat-generating, long lived radioactive waste, and a questionnaire requesting information on national approaches being adopted for the management of this waste type was later sent to the members of WASSC. A technical committee examined a revised version of the proposals document in June 2003, and, as a result, a technical document setting out elements of a common framework will be issued during 2004 to promote wider international discussion on the subject. A September 2003 draft of the technical document stated the following:

> "*In order to assure that all radioactive waste is managed in an acceptably safe manner, it has been suggested that a "common framework" should be established to provide an approach to ensuing such safe management, and particularly disposal, of all radioactive waste types consistent with internationally accepted principles of radioactive waste management…*
>
> *…The framework would provide a general understanding of:*
>
> - *the basis on which radioactive waste forms can be classified for the purpose of identifying and appropriate category of generic waste disposal options,*
> - *the identification of appropriate category of waste disposal options for each waste type that are in accordance with internationally agreed safety principles, and*
> - *the means by which the safety of such options can be assured through the development of storage and disposal systems with suitable characteristics and degrees of robustness, so as to offer an acceptable degree of protection for human health and the environment, as defined in international safety standards.*"

The outcome of such international discussions will be used to revisit the Safety Guide on waste classification, which was published in 1994 [3.4]. This work will commence in 2005. The process will entail obtaining agreement on the need for revision and the proposed format and structure of the revised guidance from the Safety Standards Committees and Commission. New proposed guidance will be drafted and sent to Member States for comment. Subsequently, the guidance will be subjected to approval by the Committees and Commission. This process normally takes two to three years to achieve consensus among Member States.

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http://europa.eu.int/eur-lex/pri/en/oj/dat/1999/l_265/l_26519991013en00370045.pdf

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4 SOURCES OF RADIOACTIVE WASTE

The purpose of this Section is to describe the sources (origins) of radioactive waste. In the first two issues of this report, this Section was used to provide a high level overview of the sources of radioactive waste. These first two issues also provided brief summaries of radioactive waste arising from current practices, both nuclear applications and the nuclear fuel cycle (NFC), and from environmental remediation activities.

Since the first issue, this Section has also described two types of large volume, low activity waste containing long lived (more than 30 year half life) radionuclides; namely, uranium mine and mill (UMM) waste and naturally occurring radioactive materials (NORM) waste. These two types of waste may require special attention within a country's overall radioactive waste management framework and, therefore, they are given special attention in the Status and Trends report series – see Subsection 4.1 and Subsection 4.2. Additionally, another type of large volume, low activity waste, commonly referred to as very low level waste (VLLW) in some IAEA Member States, also receives special attention by some Member States; see Subsection 4.3 and Subsection 8.1).

Please note that within the industrial sectors that generate UMM residues and NORM residues, not all residues may be declared or considered as waste since some may be processed further for recovery of other marketable materials. Therefore, in this section of the Status and Trends report, the terms UMM waste and NORM waste are used interchangeably with UMM residues and NORM residues. Please also note that in some Member States, there may be partial or complete overlap of UMM waste, NORM waste and VLLW. For example, a Member State may include NORM waste as a type of VLLW waste. See Section 3 regarding differences in waste classification in IAEA Member States.

Wastes arising from facility decommissioning are discussed in Section 5, "Decommissioning of Nuclear Facilities".

4.1 Uranium Mining and Mill (UMM) Wastes

Uranium mining and mill wastes, due to the long lived radionuclides they contain, can make a significant environmental impact on air, soil, surface water and groundwater. The large amounts of UMM wastes that have accumulated at mill sites also contain hazardous chemicals from milling operations as well as ore processing waste materials. The radioactivity remaining in residue materials after the recovery of uranium is about 85% of the radioactivity of the original ore mill feed.

The first Status and Trends report noted that although there are sites throughout the world contaminated with radioactivity from the front end of the NFC (extending from the mining of uranium ore through to the delivery of fabricated fuel elements to a reactor site), there is no consensus on the extent of site remediation that is required. However, since the first Status and Trends report was issued, some progress on this issue has been achieved [4.1],[4.2].

The second Status and Trends report noted that given the scale of remediation operations on UMM sites, the cost of additional exposure and the cost of the remediation had to be balanced against the environmental benefits and that solutions are likely passive, low cost, low intensity and low maintenance solutions. Two examples were given of UMM waste management, at Sierra da Estrela in Northern Portugal and at Cigar Lake in Saskatchewan, Canada.

The third Status and Trends reported on an IAEA Coordinated Research Project (CRP) on the long term management of UMM residues to cover the sharing of practical experience. The final report for the CRP was published in 2004 as an IAEA Technical Document that aims to give a comprehensive overview of UMM residue management [4.2].

Since the third Status and Trends report, the issue of small scale UMM sites was extensively covered in February 2004 at an international workshop held in Portugal, see Subsection 10.3 [4.3].

As an example, the approach followed in the USA was reviewed and is summarized next.

4.1.1 Topical Issue – UMM Tailings Reclamation in the USA

In the United States of America, a growing appreciation of the extent and severity of damage that has accumulated in the natural environment resulting from ineffective regulatory oversight in governing mine discharges, hazardous waste disposal, and un-reclaimed mining sites, led to the passage, beginning in the 1970s, of several US Federal and State laws designed to protect air, water, and land resources. Environmental effects traceable to uranium extraction and beneficiation include direct disturbances of the natural surface environment, radionuclides present in the waste products from mines and mills, increased surface water runoff from mined areas, erosion by wind and water, and contamination of nearby groundwater reservoirs.

In the USA, there are three regulatory agencies that have the most impact on reclamation of conventional UMM tailings sites:

- The U.S. Nuclear Regulatory Commission (NRC) regulates the possession and use of radioactive materials defined as source or by-product material (see definitions below). The NRC is the primary agency in the review and approval of all reclamation/remediation plans for mill sites and tailings.
- The U.S. Environmental Protection Agency (EPA) regulates the sites through various regulations concerning air and water quality. With certain exceptions, the EPA relies upon the NRC to effectively enforce these regulations through a memorandum of understanding between the two agencies.
- State environmental regulatory agencies regulate air and water quality for the mines (i.e., excluding the mill site and tailings), issue mine permits, review and approve reclamation plans for the mine, and has input via the NRC concerning the environmental impacts of the mill site and tailings.

The roles of these various agencies concerning the disposal of radioactive wastes typically associated with uranium ore processing sites depends upon the nature of the radioactive material and its definition under federal law. Basically, the NRC acts as the lead agency if the material is defined as:

- “source material”: either the element thorium or the element uranium, provided that the uranium has not been enriched in the isotope uranium-235. Source material also includes any combination of thorium and uranium, in any physical or chemical form, or ores that contain by weight one-twentieth of one percent (0.05%) or more of uranium, thorium, or any combination thereof. Depleted uranium (left-over from uranium enrichment) is considered source material [4.4].
- “byproduct”: The Atomic Energy Act, as revised in 1978 [4.5], defines byproduct material in Section 11e.(1) as radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material. The definition in Section 11e.(2) is the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content [4.6].

If the uranium ore has never entered the “restricted area” [4.7] or there is radioactive material resulting from other than the above identified categories, that material is regulated by the relevant State environmental regulatory agency or, in some cases, by the EPA.

Mine Reclamation

For open pit mines, the principal environmental concerns involve the excavations and associated waste piles. Such mine pits may require backfilling, or their pit walls may have to be reshaped to eliminate steep high slopes. Waste piles may have to be contoured to a more natural shape. The disturbed site then must be covered with original topsoil (which has been stored separately) for reseeding as necessary to establish vegetation. To enhance its long term survival, the vegetation selected should be indigenous to the area.

Other than a mandatory requirement to close shafts and mine openings, underground mines generally have few reclamation requirements.

Mill Decommissioning

The initial phase of mill decommissioning consists of the preparation of a decommissioning plan for submittal to the NRC. Primary areas of concern upon the part of the NRC are the location and means of burial of wastes resulting from the decommissioning, proper decontamination and release procedures for salvaged equipment leaving the restricted area, and radiation safety procedures for the workers involved.

Tailings Reclamation

Design Criteria

NRC regulations in Appendix A to 10 CFR 40 [4.8], which incorporate EPA regulations such as 40CFR 192 [4.9], provide the basic requirements for the operation and the reclamation of UMM tailings sites. Those reclamation requirements consist of the following:

- Erosion stability: the tailings must be covered so that the radiological hazard is controlled for 1 000 years, to the extend reasonably achievable, and, in any case, for at least 200 years.
- Radon releases: the cover must act to keep average radon releases less than 740 mBq/m^2s (20 pCi/m^2s) over the life of the cover.
- Soil decontamination: areas subject to decontamination must be cleaned up to the extend that Ra-226 levels in the upper 15 cm of soil are no more than 185 mBq/g (5 pCi/g) above background.
- Groundwater restoration: groundwater contaminated by seepage from the tailings must be cleaned up to standards for various heavy metals and radionuclides that are site specific, but generally tied to EPA drinking water standards.
- Property transfer: upon completion of site reclamation the mill site and tailings lands must be transferred to the United States or to the State.

Reclamation Design Guidance

In order to accomplish the regulatory goals above, the NRC has developed a guidance document [4.10] as an aid to a site owner in developing a site restoration/reclamation plan. In theory, designing the site reclamation in conformance with the guidance document will result in adequate erosion stability and isolation of radiological hazards. The guidance document utilizes very conservative design criteria relative to erosion analysis, and cover design and placement.

The NRC relies upon a computer model to assess the adequacy of radon barrier design. Acceptable radon barrier designs typically entail the use of either stringently compacted clay material, or correspondingly thicker layers of less desirable material.

Additional factors that must be addressed in the design are tailings consolidation, seismic stability, and the potential for intrusion of the cover by plants or burrowing animals.

Another notable aspect of the NRC's design guidance is construction quality control and assurance. In order to satisfy the NRC in this regard, frequent and costly testing of materials and their placement is required.

Surety for Site Reclamation

On approval of a proposed decommissioning plan by the NRC or State, the licensee must also provide a surety to guarantee that funds required to reclaim the site will be available to complete site restoration work to standards established by Federal and State regulations, with the assumption that a third party might be required to do the work if the licensee is unable to complete the task. The NRC or State and the licensee must agree on the estimated cost for decommissioning work. The surety amount must cover a number of activities, such as facility decommissioning, tailings reclamation, groundwater restoration, well-field closure, surface decontamination, re-vegetation, and long term monitoring. The cost estimate and surety must include a fee set by the NRC or the agreement State for funds necessary for the long term surveillance and monitoring of the site to protect public health and safety. For each license, the surety is reassessed annually to accommodate inflation and to take into account decommissioning work completed up to that time.

Examples of Tailings Reclamation [4.11]

Following are two examples of tailings reclamation conducted by Pathfinder Mines Corp (PMC) in Wyoming, USA. After the end of mining and milling operations at its two facilities, Lucky Mc Mine and Shirley Basin Mine, PMC has undertaken the reclamation of the two sites.

<u>Lucky Mc Mine</u>

18 000 tU (tonnes-uranium) were produced at Lucky Mc Mine by open-pit mining and acid leach process from 1958 to 1988. Approximately 10.6 million tonnes of tailings are stored in three different ponds originally constructed in a drainage. Adjacent to the solid tailings ponds are three ponds that contain process water solution. The total area directly impacted by tailings is approximately 162 ha with another 81 ha affected by windblown tailings contamination.

The Lucky Mc tailings reclamation plan, submitted on July 1992, was approved by the NRC on November 1999. The objectives were to develop a reclamation plan that will stabilize the tailings and solution ponds for at least 1 000 years and to clean up the adjacent contaminated materials.

The Lucky Mc mill was demolished in 1993, and all contaminated materials were buried in one of the tailings ponds. Windblown tailings contaminated areas, outside of the restricted area boundary, have been cleaned up and materials (402 000 m^3) placed in the tailings area. Tailings reclamation started in 1999, after consolidation was reached on most of the areas. The solid tailings and solution ponds have been covered with compacted clay (1.6 million m^3, up to 1 m thick). Most of the tailings and solution ponds areas have been covered with filter bed (240 000 m^3) and rock mulch (154 000 m^3) to prevent erosion. Top soil (86 000 m^3) has been placed on flat areas of the tailings ponds and rock cover has been used to stabilize steep channel sections.

Tailings reclamation at Lucky Mc Mine was almost completed in 2002, and the last solution pond should be reclaimed in 2004 after evaporation of the remaining contaminated solutions.

<u>Shirley Basin Mine</u>

9 460 tU were produced at Shirley Basin through underground, in-situ leach and open pit mining, from 1959 and 1982. Approximately 7.8 million tonnes of tailings are stored in three adjacent ponds over an area of 133 ha. Tailings windblown contamination originally extended over an additional 40 ha.

A tailings reclamation plan was submitted to the NRC in October 1983. The reclamation plan included putting the tailings into a stable configuration, covering then with a radon barrier, and emplacement of rock to control erosion. The plan was approved by the NRC in November 1999.

A cost estimate for completing the tailings area reclamation came to be significantly higher than anticipated, the purchase of the rock being the most expensive item of the plan, Therefore a new design that would reduce the reclamation cost, but still meet all NRC technical criteria, was developed and submitted in October 2001. The new tailings reclamation plan was designed with five benches at different elevations, with small slopes to reduce flow velocities and minimize the potential for erosion. Limits between the benches were determined in order to optimize cut and fill balance within each area. Flat areas would be covered with topsoil and seeded, instead of rock protection in the initial plan. Rock mulch and rubble sustaining walls (riprap) would only be used to protect aprons between the benches and in channels. The new plan was approved in 2003.

The Shirley Basin mill was demolished in 1994-1995 and all contaminated materials were buried in one of the tailings ponds. Windblown tailings contaminated areas have been cleaned up and materials placed in the tailings area. An interim cover (clay) has been placed over the tailings in order to prevent additional windblown contamination.

After consolidation of the tailings, tailings reclamation will start during the 2003-2004 winter, and should be completed in 2007. Reclamation quantities include 1.6 million m^3 of tailings regrading, placement of 434 000 m^3 of clay, 217 000 m^3 of sand, 65 000 m^3 of rock, and 334 000 m^3 of top soil.

Costs of environmental management after closure

Costs of environmental management after closure consist primarily of reclamation and monitoring costs. For uranium mills, these costs include mill decontamination and demolition, long term tailings stabilization, and groundwater remediation. For mines, the reclamation costs incurred cover partial backfilling of pits, stabilization of waste rock piles, re-contouring the disturbed land surfaces, and re-vegetation. Monitoring is a post-closure cost for both mills and mines.

Costs for mill site and tailings decommissioning are very variable. Total costs, including mill and tailings decommissioning and ground water restoration for 12 sites in Colorado, New Mexico, Texas, Utah and Wyoming range from $1.7 / ton of tailings to $12 / ton of tailings, with an average cost of $4.0 / ton of tailings.

4.2 Naturally Occurring Radioactive Material (NORM) Waste

The IAEA defines NORM as [4.12]:

> *Material containing no significant amounts of radionuclides other than naturally occurring radionuclides.*
>
> *The exact definition of 'significant amounts' would be a regulatory decision.*
>
> *Materials in which the activity concentrations of the naturally occurring radionuclides have been changed by human made processes are included. These are sometimes referred to as technically enhanced NORM or TENORM.* **[Note, please see Subsection 3.1, page 25 concerning a change in philosophy regarding the distinction of NORM and TENORM]**.

NORM wastes commonly result from the extraction and processing of natural resources, such as oil and gas, coal and mineral resources as well as other activities. These residues have developed over the past three decades from a little known issue to one that is receiving a considerable amount of attention for the following reasons:

- there are large amounts of such material,
- there are potential long term hazards because NORM wastes are comprised of long lived radionuclides with relatively high radio-toxicities, and
- there is a higher likelihood for members of the public to be exposed to NORM contained in wastes and products than for many other sources of radiation.

The first Status and Trends report identified NORM waste as a special class of radioactive wastes for which international regulation does not yet exist, but noted increased attention from a number of organizations. Some information on the size and extent of the issue was given and further reading was suggested.

The second Status and Trends report noted a move in attention away from exposure at the workplace and radon in residential housing, since these could be addressed with relative ease and limited cost. Whether this was true for less developed countries was queried. Focus had shifted to NORM waste management and its environmental impact. It was also noted that awareness from the potential radioactive contamination was high in certain metal industries, notably the steel industry where large quantities of recycled scrap are used. Conversely, the situation is different at the front end of the material streams, where large quantities of mining and milling wastes arise, some of which may be contaminated.

The third Status and Trends report noted the planned publication of an IAEA Technical Report (now published as Technical Report 419 [4.13]), that has the following objectives:

- to provide the first step in an effort to develop a global knowledge base on the occurrence and characteristics of NORM in a wide variety of industrial and domestic activities, and
- to identify and assess potential technologies that have been or could be used to help reduce the potential for exposures.

Technical Report 419 identifies industrial processes involving NORM and identifies the products, by-products and residues that are of interest. It includes an analysis of when and where the relevant processes and concentrations of NORM can be significantly enhanced and where there is an enhanced potential for human exposure. Possible changes in production and waste management technologies in order to reduce the arisings of wastes or their radioactivity are covered, as well as technologies that can be considered for the remediation of sites contaminated with NORM.

Technical Report 419 concludes with a number of important observations:

- Changing processes to avoid NORM containing raw materials is not so much a technological challenge as an economic one.
- NORM related problems are mainly associated with the extraction and processing of raw materials.
- Technologies to condition and dispose of NORM residues exist, but their economic applicability largely depends on the volumes of material arising.
- Given the long half lives of the relevant radionuclides (mainly the uranium series) the question of long term stewardship and monitoring arises and is increasingly being discussed.

Many member states are now aware of the NORM waste issue and are going through a phase of assessment. Taking action to address what can be a daunting challenge may require significant resources. However, a recent publication on the china clay industry in the United Kingdom (UK) serves as a good case study on how the challenge presented by NORM wastes can be met [4.14].

This study documents the occurrence of radioactive scale in China Clay refining in Cornwall, UK, where deposits have been mined for almost 250 years. The raw material, comprising mainly kaolinite, partly kaolinized feldspar, mica and quartz, is subjected to a number of physical separations to increase the kaolinite component and achieve the desired grain size. The proximity of the deposits to high grade uranium ores gives rise to the risk of their entrainment with the clay during extraction and concentration by subsequent treatment.

Radioactive scaling was first discovered on pieces of process pipe work at a disposal company and a subsequent radiation dose survey confirmed that the problem was widespread. Extensive characterization studies established the mineralogy, crystallography, chemical composition and radionuclide inventory of scale formed at each stage of the refining process.

Significant work was then carried out to establish a preferred technique (Ultra High Pressure water jetting) and to construct a facility for removing the scale and for processing the resulting slurry (comprising scale, associated minerals corroded metals and large quantities of water) into a suitably stable waste form.

In developing the preferred management option, several assessments were carried out to underpin the decision making process. These included a best practicable environmental option study to support the technology selection process, an environmental impact assessment to determine the potential effect of the proposed refurbishment plant on the local environment, a radiological risk assessment and a hazard and operability studies risk assessment.

Many of the techniques used in the study are seen as applicable elsewhere, given the similar geological occurrence of kaolinite deposits and the relatively standard procedures used in China Clay processing worldwide.

The third Status and Trends report also noted that comprehensive surveys of NORM residues had been undertaken for Europe and the United States of America but that information for the rest of the world was scarce. This gives rise to concern for a number of reasons, principally that a large percentage of world mining operations takes place in less developed countries that have limited resources to deal with their legacy. The report also noted the regulatory aspects of NORM and the lack of an international consensus. To address this issue, the reported noted that there was ongoing work to clarify the interpretation of the Basic Safety Standards [3.9] covering the generic principles and criteria for exclusion, exemption and clearance – see Subsection 3.1.

4.3 Very Low Level Radioactive Waste (VLLW)

As highlighted in the third Status and Trends report, the classification of large volume, low activity waste as VLLW has been adopted by some IAEA Member States. However, there may be partial or complete overlap of this waste class with UMM waste and NORM waste in the classification schemes used by other Member States (see Section 3 regarding the issue of radioactive waste classification world wide).

VLLW may be generated in a wide range of activities within the nuclear fuel cycle, within nuclear applications in hospitals, research and industry, and within non-nuclear industries. In particular, the decommissioning of nuclear facilities (see Section 5) can also give rise to large volumes of VLLW. Presently, there is no internationally agreed definition of VLLW. The definition can vary from one Member State to another but it is generally accepted that VLLW is a subset of LILW and has activity at levels that some jurisdictions may class as exempt or cleared from nuclear regulatory control.

There is, as yet, no clear international consensus on the management of VLLW. For example, with regard to disposal, while it is clear that VLLW does not pose a sufficient enough radiological risk to warrant disposal in an engineered LILW repository, disposal has taken place in or is planned for LILW repositories some Member States. In some other Member States, such as Sweden, Japan and France, disposal has taken place in or is planned for dedicated repositories for VLLW that have minimal engineering. See Subsection 8.1, "The VLLW Repository in Morvilliers, France".

However, it is recognized that many Member States are still waiting for further actions to be taken on the basis of future guidelines and direction, for example from the IAEA, and steps other countries are taking towards the disposal of VLLW.

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5 DECOMMISSIONING OF NUCLEAR FACILITIES

The purpose of this Section is to describe the status of and trends relative to nuclear facility decommissioning, where a nuclear facility is defined as [4.12]:

> *a facility and its associated land, buildings and equipment in which radioactive materials are produced, processed, used, handled, stored or disposed of on such a scale that consideration of safety is required*

and decommissioning is defined as [4.12]:

> *Administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility. This does not apply to a repository or to certain nuclear facilities used for mining and milling of radioactive materials, for which closure is used*

Experience gained in nuclear decommissioning can be categorized in three major phases. The experience of the 1980s mostly involved relatively small projects on research reactors or prototype facilities. At that time, only feasibility studies or preliminary plans to decommission larger nuclear facilities were generally available. Experience gained on the decommissioning of larger nuclear facilities, which has become available over the 1990s, has somewhat altered the picture. In many industrialized countries, the total dismantling of major prototype facilities such as the Kernkraftwerk Niederaichbach (KKN, see Subsection 5.2.6) reactor in Germany, the Shippingport nuclear power plant (NPP) in the USA and the Japan Power Demonstration Reactor in Japan has been viewed by the operators and the government decision makers as an opportunity to demonstrate to the public that the decommissioning of major nuclear facilities can be conducted in a safe and cost effective manner. Equally important, these decommissioning efforts also served to test and optimize decontamination and disassembly techniques and to create a "decommissioning market" including specialized suppliers and contractors.

The new century has brought along an impressive heritage of advanced technology in the industry such as electronics, robotics and computing. Decommissioning technologies have greatly benefited from those advances and are now ready to face the challenges of a large number of commercial facilities that will soon reach the end of their operational lifetime and become candidates for decommissioning. While individual technologies have reached maturity across a range of decommissioning aspects such as characterization, decontamination, dismantling or waste management, further efforts are needed for the integrated management of large scale decommissioning projects with a view at resource optimization. To this end, consideration of aspects somehow disregarded in the past may play a major role in such an optimization and may reduce decommissioning costs appreciably. This is the case of reuse of decommissioned sites (Subsection 5.1), which opens new prospects neglected at the time when decommissioning was basically demolition and clearing contaminated debris from the site. Selected ongoing, large scale projects are discussed in Subsection 5.2. Progress achieved with those projects is a measure of decommissioning industry maturity and it highlights various issues (funding, societal impact etc.).

In parallel with the magnitude of decommissioning programmes, several Member States developed new organizational structures to deal with ongoing and planned decommissioning projects in an integrated manner. A few examples are provided in Subsection 5.3.

Particularly in a deferred dismantling strategy, record keeping is essential to ensure that historical knowledge of and operational experience with a nuclear facility is properly described and maintained. This issue, the importance of which was also identified during the first Review meeting of the Joint Convention (see Table 2-1), is elaborated in further detail in Subsection 5.4.

5.1 Reuse of Decommissioned Sites

In the coming decades, a large number of nuclear installations will reach the end of their useful lives and require decommissioning. The conventional approach of returning a site to a "greenfield" [2] status does not recognize the important role that reuse of the facility or its constituent parts might play in contributing to a positive outlook for the decommissioning project and its stakeholders.

Examination of the role of nuclear decommissioning in the move towards sustainable development suggests that this potential for redevelopment should not be ignored. Sustainable development implies the need to combine economic development with conservation of natural resources such as land. In the case of decommissioning, the recycling of land implied by redevelopment of a site offers a valuable means of avoiding the need to further develop green field sites. Sustainable development also implies economic development with maintenance of social and community integrity. Both of these can be served by the sensitive redevelopment of sites to provide continuity of employment and new productive activity.

As a consequence of the value of the land released by decommissioning, it is likely that clearance of one activity from the site will lead to site reuse in a new activity. Most nuclear installations benefit from a level site, good access to utilities, transport and other communication links and a skilled local workforce, all of which are conducive to rapid redevelopment. In some cases, non-nuclear spin-off activities are already established on the site before the end of nuclear operations and provide the basis for regeneration of the site in a new role.

Given that this is the case and that decommissioning of nuclear installations will usually be followed by site redevelopment, is it reasonable to consider the implications of deliberately planning for decommissioning as redevelopment. This is considered in Table 5-1.

5.1.1 Policy Issues in Planning for Redevelopment

The future for decommissioned sites can take many different forms. Some may be cleared and cleaned completely to be open for unrestricted use by others. A specific reuse may be planned for the long term or perhaps only for the short term, possibly for equipment storage, temporary offices, waste storage etc. Some sites have found beneficial reuses for parts of sites and decommissioned facilities in their continuing R&D missions. Certain commercial nuclear power plant operators have elected to replace the nuclear heat source with a conventional fossil-fuelled heat source and reuse the site for continued electrical generation. Two such cases were Pathfinder and Fort St Vrain in the USA [5.1], [5.2].

If the work required to return a nuclear site to its natural or baseline state is compared with that likely to be required in preparation for redevelopment, it is likely that in many cases the redevelopment option would require less work. For example, it would not be necessary to demolish any structures that were to be retained for reuse and it would not be necessary to restore any ground that was to be covered by new development. One example of structures that were reused for new purposes (with some adaptations) is the "Vaposphere" facility at Argonne National Laboratories (ANL) in the USA (see Figure 5-1).

For some nuclear sites and in some regulatory regimes, it is economically impossible in the short term to meet the radiological criteria for de-licensing. This arises where the conditions for de-licensing are based on a 'close-to-zero' contamination or 'close-to-zero' hazard criterion and a residual hazard, such as arises when low levels of ground contamination is sufficiently dispersed, that remediation techniques are unable to restore it economically. In these cases, the only course of action available to operators who want to free themselves from the liabilities associated with the site is to transfer the ownership and operating license for the site to some new user. If the new owner is not in a position or

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2 greenfield site: a site that has been granted unrestricted release from regulatory control, buildings have been demolished and the land is return to "undeveloped" status

prepared to take over the liabilities associated with the post-closure management of any remaining parts of the site, it is possible in some regulatory regimes that under certain conditions the State takes title.

Table 5-1: Differences in Approach between Demolition and Redevelopment

Perspective	Decommissioning and Demolition	Decommissioning and Redevelopment
Functional	Structures and assets with no useful function are removed.	Structures and assets with functional value for the next use of the site are retained and may be re-configured for a new use.
Physical	The site is returned as close to its pre-development state as possible.	The site is transformed into new industrial, commercial, recreational or residential property, possibly with portions of the facility retained.
Nuclear Regulator	The existing operator or owner must remove nuclear hazards as required by law.	Ownership of the site is transferred during or after the elimination of nuclear hazards.
Risk-based cleanup	Most conservative risk assumptions are used to determine remediation goals.	The proposed new site use determines the remediation goals, consistent with protection of human health and the environment.
Community	Economic activity associated with the site is lost.	New economic activity replaces economic activity lost by closure of the nuclear facility.
Decommissioning Planner	The decommissioning end point is defined by what is known about the original state of the site and current legislative requirements.	Identification of the decommissioning end point depends on planned end use and any redevelopment agreement.
Liability Management	The owner remains liable for future harm caused by any failure to completely restore the site.	The owner transfers the site and possibly the residual liabilities to the new owner
Resource Use	The land occupied by the nuclear facility is unavailable for use during decommissioning, demolition, and restoration. The subsequent lead-time needed for any new use will further delays access to the resource.	The land is returned to use earlier, enabling development on a brown field site rather than on more sensitive or valuable land.
Financial	Cash flows are negative until the completely restored site is leased or sold.	Costs of decommissioning and restoration are reduced, can be offset by the development value of the land, and are recovered more quickly.
Decommissioner	The decommissioner is free to plan and execute the work within financial and regulatory constraints.	Planning and execution of decommissioning must be done in consultation with the developer to maximize the redevelopment value of the site.
Long term Stewardship	The owner remains responsible for monitoring residual contamination and continues to maintain any institutional controls.	Management of all site activities becomes the responsibility of the new owner.

Figure 5-1: The Vaposphere at Argonne National Laboratories, USA
(this facility was "free-released" for unrestricted reuse by ANL operations)

5.1.2 Social Factors

Public concern over social issues can eliminate redevelopment options that are under consideration. This was the case in the planning for the reuse of the Barseback site in Sweden where the local community preferred to use the space for re-development as housing while the local governmental authorities planned to take advantage of the available infrastructure and to reuse the site for electricity production using a different heat source [5.3].

5.1.3 Conclusions

In the coming decades a large number of nuclear installations will reach the end of their useful lives and require decommissioning. Many of these installations will be decommissioned with the aim of replacing them by new installations that may serve the same purpose or another completely different purpose. By recognizing and promoting the redevelopment potential of sites early in their life, it is possible to enhance the prospects for worthwhile redevelopment offsetting the costs of decommissioning and ensuring that best use is made of the material and land resources associated with the sites.

5.2 Recent Decommissioning Experiences

A large number of major decommissioning projects are active world wide. In the United States of America, one might select to quote the nuclear sites of Rocky Flats (see Subsection 5.2.1) and West Valley and the following NPPs: Connecticut Yankee, Yankee Rowe, Maine Yankee, Fermi 1 (see Subsection 5.2.2), Saxton, Rancho Seco (see Subsection 5.2.3), San Onofre Unit 1, Big Rock Point, and Trojan. In the United Kingdom, noteworthy decommissioning projects include the NPPs at Berkeley, Trawsfynydd, Hunterston A, Hinkley Point and Windscale Advanced Gas Cooled Reactors (AGR) (see Subsection 5.2.4). In France, the notable decommissioning projects are Brennilis EL-4 Heavy Water Reactor (HWR), Chinon A2 Gas Cooled Reactor (GCR), Bugey 1 (GCR), and Chooz A Pressurized Water Reactor (PWR) NPPs (see Subsection 5.2.5). In Germany, key projects include the Würgassen and Greifswald NPPs, the Multi-Purpose Research Reactor, the Compact Sodium-Cooled Nuclear Reactor Facility (KKN) (see Subsection 5.2.6) and the Karlsruhe Reprocessing Plant. Other projects are underway in Belgium, Italy, Spain etc. The cited subsections provide some examples of ongoing decommissioning projects, with the aim of illustrating typical activities and highlighting progress achieved.

5.2.1 Rocky Flats Site, USA

Rocky Flats is a US Department of Energy (DOE) owned cleanup and closure site operated by the Kaiser-Hill Company under an accelerated closure contract. The Rocky Flats mission includes special nuclear material management and shipment, nuclear deactivation and decommissioning, waste management and shipment, environmental cleanup and site closure. [5.4].

Rocky Flats achieved an historic milestone in August 2003 by removing the last remaining weapons-usable nuclear material, allowing closure of the final high security plutonium handling and storage operation on site (see Figure 5-2).

This achievement decreases the level of risk for the site and surrounding communities while saving nearly $US 2 million in monthly security costs that now can be applied directly to cleanup projects.

Left Picture – (Before) The XY Retriever was one of several highly contaminated plutonium vaults that now stand empty
Right Picture – (After) Removing the site's weapons usable nuclear material allowed D&D of the XY Retriever

Figure 5-2: Recent Progress in Decommissioning at Rocky Flats

More than 2 000 special shipping containers carrying packages of plutonium metals, oxides and composites and several hundred containers of enriched uranium were packaged and shipped to other DOE Weapons Complex sites over an eight year period. Rocky Flats cleanup and closure is currently progressing under budget and ahead of schedule for the December 2006 closure date.

While new technology was developed to process, package and transport the site's special nuclear material, many of Rocky Flats' most successful achievements resulted from adapting existing technology to the site's needs.

A recent example involved modifying a lifting device commonly used by the aviation industry to facilitate decontamination and dismantlement (D&D) waste removal from the second floor of Building 776/777.

By loading D&D waste directly into cargo containers, then lowering them to the ground and removing them by a fork truck, the project was able to increase worker safety and drastically cut the time required to remove waste from the second floor (see Figure 5-3).

The modified MDL-40 allows crews to load waste directly into a cargo container from the 2nd floor

Figure 5-3: Efficient Waste Removal Activities at Rocky Flats

Since January 1995, the site has shipped nearly 105 000 m^3 of low-level, more than 40 000 m^3 of low-level mixed and 8 000 m^3 of transuranic and TRU-mixed waste (US classifications, see Section 3).

On 8 November 2003, Rocky Flats' most visible structure was demolished. The 50-year old water tower was safely razed using small-scale explosives. Workers also demolished the site's last guard tower and a ~31 metre high ventilation stack.

The three demolitions bring the number of buildings and structures removed or demolished from Rocky Flats to 315 out of more than 800 original buildings.

5.2.2 Fermi 1 NPP, USA (status as reported October 2003)

The Fermi 1 Decommissioning Project team successfully reacted the sodium and sodium-potassium (NaK) residues in two vapour trap systems in the summer of 2003 [5.5]. This effort followed months of set-up of the necessary piping systems and preparation and review of procedures. The team used steam in a nitrogen atmosphere to convert the sodium and NaK to sodium hydroxide, potassium hydroxide and hydrogen. The nitrogen and hydrogen effluent was scrubbed of particulates, filtered, monitored and released. The hydroxide was neutralized. Processing of primary sodium containing pipe in a reaction chamber also commenced in the summer of 2003. The team has successfully processed more than a dozen tanks and other large components containing sodium product residues to date. Preparations continue for future sodium processing.

One group is cutting sheathing from around the primary sodium system piping in the Reactor Building basement and another is fabricating the next processing system components. A third group is working on processing using the reaction chamber and a fourth is removing gravel from under the floor and cutting a hole in the maintenance pit wall, so that a safer access can be installed to a room containing two sodium tanks underneath the floor. Considerable work has and is being performed to improve access to the equipment being processed or removed. Much of the equipment at Fermi 1 is located in shielded compartments underneath the operating floor or behind concrete walls. These features provided good shielding and isolation from a sodium mishap during plant operation, but make the decommissioning challenging. Typically, the only access is through a top manhole. Safer access and exit pathways are being installed in several work locations.

Other highlights include completing the cutting and proper disposal of the reactor machinery dome (its paint included both PCBs and lead) and removing the majority of cables from the Reactor Building.

The removal of all equipment, to be taken away as part of the decommissioning project, is expected to be completed in 2007. License termination is expected in 2009.

5.2.3 Rancho Seco NPP, USA

Decommissioning of the Rancho Seco NPP includes the following highlights:

Spent Fuel Pool – Liner removal is in progress by use of a milling apparatus that cuts the welds between panels and wall embeds. All remaining water on-site with significant boron or tritium has been processed and released. Planning for soil sampling and analysis under the pool is in progress.

Figure 5-4: Cutting the Spent Fuel Pool Liner at Rancho Seco NPP

System Dismantlement – System dismantlement continues in the Auxiliary and Reactor Buildings. Auxiliary Building work includes remaining ventilation and electrical systems in contaminated areas and general area preparation for characterization surveys. Structural steel and electrical systems continue to be removed in the Reactor Building.

Large Components – Cutting of the vessel head was completed in January 2004. Cut into five pieces, the head was shipped and disposed of for significantly less cost than an intact shipment. The pressurizer is scheduled to ship to Envirocare first quarter of 2004. Preparation of these components is in progress. The steam generators should go to Envirocare by rail in 2005 but will require cutting in half. Steam generator penetration closures are being installed and the necessary transportation exemptions are being pursued. Detailed characterization of the vessel and internals is complete.

Outside Components – Work was completed on dismantlement of the large outside tanks and remaining contaminated outside systems. These include the Borated Water Storage Tank, the Demineralized Reactor Coolant Storage Tank and the Spent Fuel Cooler. Underground piping removal will begin in 2004.

License Termination Plan (LTP) – Work has begun on the LTP. Initial meetings with the Nuclear Regulatory Commission (NRC) are planned for spring 2004. Characterization work is ongoing to support this effort.

Site Re-Powering – In 2003, the Sacramento Municipal Utility District (SMUD) received final state approval for a 500 MW natural gas fired plant on utility property [5.6]. SMUD hopes to be generating electricity from natural gas fired turbines by the summer of 2005.

The plant would allow SMUD, the region's biggest electric utility, to create more of its own power, making the energy supply more reliable and reducing the district's exposure to the often volatile wholesale energy markets.

The plant would be on a 12 hectare parcel nearly a km south of the Rancho Seco nuclear plant. Putting the plant at Rancho Seco would allow the reuse of existing water systems, switchyards and transmission lines. The site sits on a piece of property already owned by SMUD, which also eases construction and lowers costs (see Subsection 5.1).

5.2.4 UK NPPs

Background

The commercial nuclear power stations in the UK are owned by two utilities: British Nuclear Fuels Limited, BNFL (with Magnox Electric as its operating arm) and British Energy. BNFL owns 26 gas-cooled, graphite moderated Magnox reactors of which 14 have been permanently shutdown. The rest will be progressively closed during the period 2004-2011. British Energy owns 14 AGR and one PWR. These are all operational and there are no immediate plans for shutdown. The prototype nuclear stations are owned by the UK Atomic Energy Authority (UKAEA): these are all shutdown [5.7].

Decommissioning Strategy

The UK does not have a disposal site for much of the activated radioactive wastes that will be generated from reactor decommissioning, and is unlikely to have one for many decades. Magnox reactors are huge. The steel pressure vessel and graphite core together weigh around 5 000 tonnes and were built on site. The Magnox reactor fleet is constructed primarily from low cobalt carbon steel so dose rates drop after shutdown to the point where continuous activities by personnel inside the bioshield are possible several decades after shutdown. Gas-cooled reactors must be dismantled on site and personnel access would greatly help this process.

Significant quantities of activated radioactive waste originating from fuel components are stored on UK gas-cooled reactor sites. The UK has nuclear fuel reprocessing facilities at Sellafield. As a result, the UK's decommissioning strategy is to defuel the reactors, dismantle all power station buildings except the reactor buildings, then “Safestore” the reactors for a period of up to 100 years. The more chemically reactive operational wastes will be retrieved, packaged and stored on site awaiting a final disposal route. See Subsection 5.3.1 for more information on the UK’s decommissioning strategy.

Physical Decommissioning Progress

Six of the BNFL Magnox reactors have been fully defuelled at Berkeley in England, Trawsfynydd in Wales and Hunterston A in Scotland and significant strides have been made in decommissioning and demolition. Defuelling is underway at Hinkley Point A, Bradwell and Calderhall. Each reactor contains around 25 000 fuel rods, each of which must be handled individually, so the process takes around three years. Design work is now complete on operational waste retrieval systems and storage facilities with a 100-year lifetime capability. Large quantities of this operational waste have already been retrieved at Trawsfynydd and have been placed in storage awaiting planning permission for long term storage.

Considerable progress is being made by BNFL, under contract to UKAEA, in the complete demonstration dismantling of the Windscale AGR (WAGR). The entire reactor is being dismantled, packaged and stored at Sellafield awaiting a disposal route. The main work to dismantle the reactor’s internal structures began in 1998 and progress since has been rapid. In early 2003, the final piece of the graphite core was removed in a top-down sequence. In all, eight layers of interlocking graphite blocks were dismantled, encapsulated in concrete and placed in a specially designed building for storage. Each layer of the core was removed brick by brick using a ball grab deployed from a remotely operated overhead crane. At the WAGR project, the latest campaign-removal of the thermal shield was successfully completed in May 2003. Details on ongoing work to develop remotely operated oxypropane cutting equipment to dismantle the core support structures and the pressure vessel are given in Reference [5.8].

A new extraction and filtration system was installed in WAGR in 2003. It provides negative pressure in the vault area and ensures complete recovery of airborne particulates created during the oxypropane cutting of remaining structures [5.9].

The programme as a whole is ahead of schedule and completion is expected in 2005. The total cost for the project is estimated at £80 million. More details on the overall WAGR project can be found in References [5.10] and [5.11].

In July 2003, the UK's 39-year old Hinkley Point A Magnox station (a twin reactor) was given the regulatory go-ahead to decommission. The task of asbestos removal has started already, which will take four years to complete. Defuelling of the reactors was nearly 50% completed in July 2003. Similarly, in December 2003 the Bradwell NPP was given regulatory consent to be decommissioned [5.12].

Public Inquiry at Trawsfynydd

The nuclear power station at Trawsfynydd in Wales is unique in being built in a National Park. This construction was sanctioned in the 1950s against a backdrop of massive regional unemployment and power shortages. The absence of a radioactive waste disposal route means this station, like the others, will be put into "Safestore" for a 100-year period and that a store for the operational waste must be built. The UK's stringent land use (zoning) legislation lead to the National Assembly for Wales, together with the UK Government, calling a Public Inquiry into this proposal on the grounds of national interest.

Because of the unique National Park location, BNFL Magnox Electric proposed lowering the reactor buildings by 20m and constructing a curved roof to blend into the surrounding mountain landscape.

The Inquiry was held in November/December of 2002 and planning permission for the work was granted jointly by the National Assembly and UK Government in July 2003.

5.2.5 French NPPs

Brennilis NPP

Brennilis will be the first Electricité de France (EDF) NPP to be fully dismantled ending with release of the site [5.13]. Dismantling activities started in 1997 with the dismantling of electromechanical equipment from auxiliary buildings and the conditioning of dismantling wastes. These wastes were shipped to a repository operated by ANDRA (Centre de Stockage de l'Aube) or to a melting and incineration facility (CENTRACO).

The remediation and demolition of auxiliary buildings started in 2000 and will be finished in 2004. In order to reduce the volume of radioactive wastes to be treated, the contamination is removed from concrete walls by hands-on or remote techniques. Therefore, the remaining structures can be considered as conventional wastes. The buildings are then demolished with conventional techniques and the rubble is unconditionally released. The French Safety Authority has approved this procedure and a first nuclear building was demolished in April 2002.

The studies for the final dismantling of the reactor building started in 2003 and will be finished in 2004. The objective is to start the dismantling of the rector vessel in 2007 and to complete it in 2012. After remediation of the reactor building, its demolition will start in 2015. At that time, the site will be cleared from any nuclear regulation and will be redeveloped.

Chinon A 2 – GCR

As a result of EDF's previous decommissioning strategy, Chinon A 2 has reached "level 2" of the decommissioning process, which can be defined as Partial Site Release. The non-nuclear part has been demolished and most of the nuclear electromechanical equipment has been dismantled to reduce the safe enclosure perimeter and surveillance activities. Only the reactor vessel and the heat exchangers remain. They will be dismantled after dismantling of the Bugey 1 reactor containment, which will constitute a first of its kind for an EDF GCR. The graphite is currently stored in the reactor vessel and some of the dismantled electromechanical equipment is currently stored in the Safe Enclosure.

Bugey 1 - GCR

The last of the graphite-moderated reactors built by EDF, Bugey 1, was shutdown in 1994. It is an integrated reactor where the heat exchangers are located under the core, both being integrated into a huge pre-stressed concrete block whose walls are 7 meters thick. As a result of this particular design, most of the equipment outside this concrete block is not contaminated and has been dismantled.

Removal of graphite fuel cladding packages started in 2002 and partial dismantling work is expected to be completed by the end of 2004. The studies for the dismantling of the reactor building started last year. Some samples were taken from inside the reactor concrete block and from the walls in order to characterize the contamination and activation of the materials. The dismantling work will start in 2008 and is planned to be completed in 2015.

Chooz A

The Chooz A NPP, located in the Ardennes region, was definitively shutdown in 1991. It is the first French PWR unit involved in the deconstruction programme. A unique feature of this site is that the reactor and its auxiliaries are installed in two rock caves excavated in a hill.

The unloading of the reactor started immediately after final shutdown and removal of spent fuel from the site was completed by 1995. After that, the safety systems related to the cooling of spent fuel were decommissioned, the circuits were drained and the spent fuel pool was decontaminated. In 1999, EDF was authorized by the French regulatory body to start the activities leading to the transformation of the plant to a Safe Enclosure as requested by the previous decommissioning strategy. The primary circuit was disconnected from the remaining part of the installation so as to confine most of the radioactive materials. Demolition of the non-nuclear parts started in 2002 and dismantling work in nuclear auxiliary buildings located on the top of the hill was completed by the end of 2003. After remediation, the buildings are considered as conventional buildings and will be demolished using conventional techniques.

As a result of EDF's new decommissioning strategy (see Subsection 5.3.2), studies for the dismantling of equipment located in the two rock caves were anticipated and started in 2003. Dismantling work on the reactor vessel will start in 2006 and is planned to be completed in 2014.

5.2.6 KKN Facility, Germany

The Compact Sodium-Cooled Nuclear Reactor Facility (KKN) was an experimental power plant that operated from 1971 to 1991. According to the decommissioning concept, the plant should be dismantled completely (green field) in 10 steps. The first eight steps have been completed already. The fuel elements and the sodium were removed, no longer required facilities and systems were shutdown, and the cooling towers and machine halls were demolished. The secondary and primary sodium cooling circuits have been disassembled completely. The rotary lid of the reactor was dismantled in 2002.

The licence for the 9th decommissioning step (dismantling of the reactor tank and biological shield) was granted in March 2001. Planning, construction and installation of the equipment required were completed in 2003. In the reactor building, an enclosure with thick shielding walls and remotely controlled handling systems will be set up above the reactor tank. For the disassembly of the reactor tank and its internals (about 43 tonnes), a specially developed and tested dismantling tool will be lowered into the reactor tank using the cell crane.

After this, the primary shield (90 tonnes) and approximately 330 tonnes of heavy concrete (biological shield) will be subject to remote dismantling.

The plant is planned to be dismantled to greenfield status by the end of 2005 [5.14].

5.3 Selected Organizational Developments

5.3.1 Future Liabilities Management in the UK

The UK Government has set up the Nuclear Decommissioning Authority (NDA) to cleanup the country's legacy of nuclear waste, a task estimated to cost around £48 billion [5.7], [5.15]. All of BNFL's and UKAEA's assets and liabilities, including the reprocessing facilities at Sellafield and Dounreay, will be transferred to the NDA. This new arrangement neither includes British Energy sites, which are not owned by Government, nor defence sites. The NDA will provide the strategic direction for cleaning up Britain's civil public sector nuclear sites. It will have due regard for safety, security, the environment and value for money. Openness, transparency and ensuring public confidence will be key principles of the NDA.

The NDA will be in a position to take decisions that balance short, medium and long term considerations. These will reflect the fact that the clean up programme has to be sustained over a period of 100 years or more.

The NDA is not intended to carry out clean up work itself. Instead, it will place contracts with site licensees, currently BNFL and UKAEA, who will be responsible for the clean up programme at each site. Site licensees will need to meet relevant regulatory requirements and incentives will be provided by contracts to drive forward the clean up work effectively and efficiently. The separation of strategy and planning from implementation will enable the NDA to focus on the strategic management of the clean up programme. This arrangement should combine the best of what the public and private sectors have to offer.

The NDA will want to maintain a presence close to many of the legacy sites, in order to manage contracts with licensees and relationships with local stakeholders. It will also require corporate headquarters. The Government announced on 11 December 2003 that West Cumbria will be the location for these headquarters, reflecting the crucial position of Sellafield within the UK's nuclear cleanup programme.

To prepare the way for the NDA, a special team has been established within the UK Department of Trade and Industry. This team, known as the Liabilities Management Unit (LMU), includes staff from both private and public sectors, and is supported by a partner contractor (Bechtel Management Company Ltd). Acquiring a detailed knowledge of BNFL and UKAEA liabilities has been an early priority for the LMU, since it provides the foundation for all the NDA's activities. In particular, it will be used to build the first National Lifecycle Baseline, the overall plan for discharging the UK's public sector civil nuclear liabilities. This Baseline will, in time, provide the basis for planning short term work programmes at each site and thereby provide the NDA with the means to drive forward and focus available resources on priority tasks [5.16], [5.17].

5.3.2 Revised Decommissioning Strategy in France

Electricité de France (EDF) has nine of its nuclear power plants definitively shutdown and under decommissioning.

Most of them are first generation units that started operating in the 1960s and were definitively shutdown at the end of the 1980s or at the beginning of the 1990s, mainly for economic reasons. They were not competitive against the new types of reactors (PWR 1300 MW and N4 series). See Table 5-2 [5.13].

Until January 2001, EDF's policy regarding the dismantling of its decommissioned nuclear power plants was to reach "level 2" (partial site release, i.e. release of non-nuclear facilities) about 10 years after final shutdown and to postpone final dismantling for another 30-40 years to take advantage of radioactive decay. This strategy was intended to satisfy three categories of stakeholders:

- the owner, because expenses were deferred,
- the operator, because there was still some activity on site, and
- the regulatory body because decision about disposal solutions could be postponed.

Table 5-2: Shutdown NPPs in France

Unit	Reactor type	Capacity	Operating life
Brennilis	HWR	70 MW	1967/1985
Chinon A1	GCR	70 MW	1963/1973
Chinon A2	GCR	200 MW	1965/1985
Chinon A3	GCR	480 MW	1966/1990
St Laurent A1	GCR	480 MW	1971/1992
St Laurent A2	GCR	515 MW	1972/1994
Bugey 1	GCR	540 MW	1971/1992
Chooz A	PWR	300 MW	1967/1991
Creys-Malville (Superphenix)	FBR	1240 MW	1986/1996

Only public opinion was cautious about the real possibility to return to green fields in a reasonable timeframe.

Today, EDF considers that if the nuclear option is to remain open, it is necessary to deal with increasing public concerns for environmental and waste management issues. Therefore, EDF and the nuclear industry have to demonstrate their ability to control the back end of the nuclear power plant life cycle. Therefore, in 2001-2002 EDF decided to achieve total dismantling of all nine already shutdown reactors in the next 25 years. This new strategy will provide the tangible demonstration of the feasibility of dismantling, from the industrial, waste disposal and financial (adequate funding) points of view.

There are several benefits to this more aggressive strategy:

- It will allow addressing safety- and environment-related issues as yet unresolved.
- The cost of dismantling first generation units will already have been met when the time comes to invest in the renewal of the operating PWR park.
- Last, it will also provide the opportunity for structuring the industrial organization and preparedness (engineering and industrial) that will be relied upon for the final dismantling of the existing PWR park beyond 2020 (32 units).

To implement this strategy, in 2001 EDF decided to set up a new Engineering Department, CIDEN (French acronym for Decommissioning and Environment Engineering Department), with 2/3 of the activity of its 400 employees dedicated to decommissioning.

The decommissioning programme of the 9 EDF units already shutdown has to be completed in 2025. It will be organized in two stages. The first stage includes:

- final dismantling of Brennilis (to green field status) in 2015,
- a dismantling demonstration of a PWR reactor building (Chooz A) before starting the replacement of PWRs currently in operation, and
- final dismantling of reactor containment of a GCR (Bugey 1) as a first of its kind.

The second stage includes:

- dismantling of five GCR units (Saint-Laurent A1 and A2, Chinon A1, A2 and A3), and
- final dismantling of Chooz A and Bugey 1 in 2025.

It is estimated that the total cost of the above programme will be on the order of 3 billion Euros. The successful implementation of this programme relies on:

- the simplification of regulatory processes and procedures,
- the availability of treatment, conditioning and disposal facilities for specific categories of wastes (graphite, sodium, long lived, etc.), and
- an effective nuclear industry (contractors and suppliers) that will ensure the technical, cost and schedule aspects of this programme.

With regard to the regulatory process, French nuclear safety authorities have issued new rules for licensing the decommissioning of nuclear installations that aim to simplify the process and make it easier for operators to draft long term plans and regulators to monitor them. Under the new regulations, a single decree will cover both permanent closure and dismantling of a nuclear installation, rather than an operator having to apply for several modifications to the shutdown decree during the dismantling process. The new regulations also allow an overall view of the project and its overall coherence [5.18].

The availability of timely solutions for managing the waste is of the utmost importance. Among them, the main critical issues are the opening of:

- a Very Low Level Waste (VLLW, French classification, see Section 3) disposal facility in 2003 with a total capacity of 750 000 tonnes (the wastes generated by EDF decommissioning programme represent 1/3 of this capacity); see Subsection 8.1,
- a new disposal facility for graphite and radium-bearing wastes (17 000 tonnes) in 2010, and
- a centralized storage facility for long lived, Medium Level Wastes (French classification) in 2007-2008 (500 tonnes, including filters, control rods, reactor internals for example)

In order to secure the execution of the decommissioning programme, EDF is considering the possibility of erecting "buffer" storage facilities on the decommissioning sites to mitigate the impact of potential delays in the licensing and commissioning of new facilities.

5.4 Record Keeping for Decommissioning

The second issue of this Status and Trends report [5.19] briefly discussed an "in press" IAEA Technical Report that covers record keeping aspects for the decommissioning of nuclear facilities [5.20]. Subsequent to its publication, this report and other issues related to record keeping in support of decommissioning were presented at an International Conference [5.21]. Highlights of the presentation follow:

When a nuclear facility is shutdown for decommissioning, current operating experience may be lost. Therefore, one important element of planning is to identify, secure and store appropriate operational records to support decommissioning. This process is preferably initiated during the design and construction phase and continues throughout operation, including shutdown. Part of the records inventory from operation will become records for decommissioning and it is cost effective to identify these records before final facility shutdown. Experience shows that lack of attention to record keeping may result in an undue waste of time, other resources and additional costs (see Table 5-3).

It is clear that record keeping in a deferred dismantling strategy poses a long term record storage issue and retrievability concerns are significantly greater than in a case of immediate dismantling [5.22]. At the beginning of dismantling, there may only be a few people having detailed knowledge of the shutdown facility. Debriefing of staff at facility shutdown (or when they leave the facility) is particularly significant for this strategy. It is important that the debriefing is structured, of good quality and is itself a well maintained record. For deferred dismantling, the opportunity to debrief personnel will probably no longer exist when decommissioning actually begins (i.e. may be decades after facility closure). Full reliance will then have to be given to records assembled during design, construction, operation, shutdown and personnel debriefs. These records will have been stored for future decommissioning use over a period of several decades. Issues for this strategy, like legibility, preservation and retrievability over such long time spans, are important.

Table 5-3: Consequences of Lack of Records for Decommissioning (Examples) (Part 1)

Types of Missing Records: Design, construction, and modifications data	Consequences
(1) Site characterization, geological and background base line radiological data	• no target for restoration of site • site termination survey more technically difficult • more time, resource, and equipment used required • future litigation due to inadequate data • significant regulator interface on the potential environmental, health and safety issues • licence termination documentation potentially large and complex • impact on decommissioning strategy and cost i.e. significantly increased waste management • considered to be a significant issue for facilities handling natural occurring radioactive material.
(2) Complete as-built drawings, the technical description of the facility, including design calculations	• complicates knowledge of and access to contaminated areas • time/money spent on reconstructing the record and calculations • the above will be needed for the safety case, which may be delayed • direct effect on decommissioning strategy – impact on time scheduling • much more safety/environmental planning to deal with unknown situations – more contingency e.g. resources and financing • considerable increased regulatory interaction to clear the safety case • cannot move to decommissioning without this data being available or reconstructed.
(3) Procurement record of materials during construction (through life)	Adequate theoretical assessment of neutron activation (for reactors) of materials is more difficult. This leads to considerably more sampling of the facility, which: • has implications on work force safety, and decommissioning costs: • can effect the decommissioning strategy regarding waste management • causes difficulty with estimating potential dose uptake. This will lead to conservative decommissioning strategies which will effect decommissioning work packages. • has implications for selection of decontamination techniques • may require more regulatory intervention for seeking assurance • affects time, resource, cost implications re strategy, time delay.

Table 5-3: Consequences of Lack of Records for Decommissioning (Examples) (Part 2)

Types of Missing Records: Operating, shutdown, and post-shutdown data	Consequences
(1) Environmental releases (over facility life)	• lack of assurance on "off site" and site contamination • public concern potential. Potential long term litigation • regulatory intervention regarding previously un revealed historical events • reconstruct data via extensive sampling • potential to be "forced" to do cleanup operations that are not the facility's responsibility • unable to adequately confirm the baseline site characteristics • potential difficulty in releasing land for other uses.

(2) Abnormal occurrence reports	• the need to deal with unknowns – can give rise to unexpected operator risk – give regulator, public, workforce lack of confidence in the management of the decommissioning
	• unexpected waste arisings and workforce dose/chemical exposure
	• impact decommissioning strategy
	  • cause delay
	  • substantial change in strategy
	• time, costs, resources – can impact the ability to release land.

(3) Records of termination of pipes/cables/vessels	• unexpected hazard arise • lack of records lead to lack of confidence by the Regulators, public, workforce • potential for cross contamination • interfere with the development of work programmes – contingency required • extensive survey will be required • additional wastes generated e.g. vessels of liquids, cells of material.

The main sources of data for a Records Management System (RMS) for decommissioning are:

- design, construction and modification data (see Table 5-3, Part 1);
- operating, shutdown and post-shutdown data (see Table 5-3, Part 2).

These sources are discussed in Reference [5.20]. When a nuclear facility is in the design and construction stage, an opportunity exists to implement both data collection and an RMS for the data as part of an integrated facility information system. The data arise from various sources (operation, maintenance, radiological protection and waste management) and in several forms (figures, images, samples, reports). The RMS can be designed to provide retrieval and manipulation of the data in a transparent way for the users. Records will be indexed by elements such as system classification, type and locations. Further, it may be particularly helpful in any such system to 'flag' data that may be of particular importance to decommissioning.

Validation of the documents and the data needed for decommissioning is essential for planning the decommissioning work programme. The process will generally result in a considerable reduction in the number of documents that had been used during facility operation. As one example, in the Brennilis decommissioning project in France (see Subsection 5.2.5), it was estimated that documents (including safety documents) useful for the decommissioning teams make up about 30% of the initial documentation [5.23].

The systematic selection of records is based on the review of existing records and their relevance to the following [5.24]:

- statutory and regulatory requirements,
- support to engineering and the safety demonstration of immediate and future facility decommissioning activities, and
- the operator's legal defence against possible future litigation.

Detailed decommissioning plans describe the planned decommissioning activities. These plans include a description of methods used to ensure the protection of workers, the public and the environment against radiation and other hazards. In addition, an estimate of the waste expected to be generated during the project is included. A detailed radiological and materials inventory is crucial to the planning of any decommissioning project. To develop these reports, information is needed, such as levels and locations of contaminants and quantities of specific radionuclides present in areas of the facility to be decommissioned.

Another input into the decommissioning plan are records of spills, or other unusual occurrences, that took place over the operating life of the facility where contamination may remain and give rise to potential locations of inaccessible or concealed contamination (e.g. under repainted surfaces or floors).

It is essential that the location, physical-chemical content and concentrations of both hazardous and radioactive wastes stored at the facility, or its site, be well documented and readily available. Of particular importance is waste and debris placed in temporary cells, pits or vaults.

The major objectives for record keeping for decommissioning are to:

- provide necessary, sufficient and up-to-date information for decommissioners and other parties to make informed decisions about planning and implementation of decommissioning actions,

  There will be significant financial consequences if there is inadequate documentation to support decommissioning.

- allow for consideration of eventual decommissioning plans during design and operation,

  By doing this, the information will be readily available and transferable as needed.

- allow, throughout the life of the facility, frequent and independent auditing of the records archive with decommissioning as a primary focus,

  The auditing process is intended to identify gaps in the RMS and address the usefulness of the archives for decommissioning.

- ensure that the information transferred to future users be comprehensible. This takes account of the fact that technologies may change and knowledge of the facility may diminish, so that information may be less understood over time, and

  Keeping control of records (and institutional knowledge) is necessary for the whole decommissioning process.

- select appropriate media to ensure durability, readability and retrievability of the information.

  Redundancy and diversity in the RMS are necessary for effective records management.

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6 PREDISPOSAL MANAGEMENT OF RADIOACTIVE WASTE

The IAEA defines predisposal radioactive waste management as [4.12]:

> *Any radioactive waste management steps carried out prior to disposal, such as pretreatment, treatment, conditioning, storage and transport activities. Decommissioning is considered to be a part of predisposal management of radioactive waste.*

Transport activities on wastes are not within the scope of this report because, technically, they do not differ from activities with other radioactive materials. The IAEA has published a set of documents dealing with the safe transport of radioactive material [6.1].

Predisposal radioactive waste management is comprised of a set of activities whose implementation may take a long time, especially if new techniques are to replace older ones. There are safety issues and important economical considerations to solve prior to taking any decision on implementing a new strategy or technology. In that sense, a major purpose of this Section will be to highlight emerging predisposal management options to waste management operators and decision makers. However, to some extent, Section 6 will also provide overviews and examples of routine activities that are already commonly practiced.

The predisposal topics discussed in the current issue of this Status and Trends report are minimization (Subsection 6.1), characterization (Subsection 6.2), processing (Subsection 6.3) and storage (Subsection 6.4).

Predisposal management encompasses all classes of radioactive wastes (see Section 3, “The Classification of Radioactive Waste”). Over the first three issues of this Status and Trends report, the following were presented:

- Issue 1: LILW minimization (organizational, technological and economical aspects), LILW processing (options), spent fuel processing (reprocessing, partitioning, and transmutation), storage (all classes, overview),
- Issue 2: LILW minimization (of decommissioning waste), LILW processing (innovative approaches), liquid HLW processing (vitrification) and storage (liquid HLW and spent fuel, examples of facilities in Europe), and
- Issue 3: LILW minimization (innovative approaches), processing (all classes - example facility), storage (all classes – example facility).

All previous issues of this Status and Trends report described the IAEA’s activities to collect and disseminate information about predisposal management activities and facilities in its Member States. This topic is described further in Subsection 6.3.2, “Collection and Dissemination of Radwaste Processing Information by the IAEA” and Subsection 6.4.3, “Collection and Dissemination of Radwaste Storage Information by the IAEA”.

6.1 Waste Minimization

The IAEA defines waste minimization as [4.12]:

> *The process of reducing the amount and activity of radioactive waste to a level as low as reasonably achievable, at all stages from the design of a facility or activity to decommissioning, by reducing waste generation and by means such as recycling and reuse, and treatment, with due consideration for secondary as well as primary waste.*

The need for waste minimization arises from the fundamental principle of radioactive waste management that "*The generation of radioactive waste shall be kept to the minimum practicable, in* *terms of both its activity and volume, by appropriate design measures and operating and decommissioning practices*” [6.2]. This principle is reflected in relevant IAEA documents as well as in regulatory and legislative documents in many IAEA Member States.

The first issue of this Status and Trends report stated that waste minimization activities should consider the following in the planning and implementation phases:

Minimization Strategy: A strategy should be established to serve as a conceptual basis for coordinated planning and implementation of desired measures. These measures should combine administrative considerations (e.g. a legislative basis, clearance policies and economic incentives) with technical and safety considerations (e.g. design principles of the nuclear facility and individual components; the expected operational lifetime of facilities; the waste conditioning strategy (national and also facility-specific); and the waste disposal strategy, scale, type and location of storage and disposal facilities).

Minimization of Arisings: Radioactive waste avoidance should begin at the design and construction phases for new facilities by the proper choice of materials (e.g., with a low tendency to activate), by the application of reliable technologies (e.g. to minimize replacement and/or maintenance), by minimizing secondary waste (e.g. from cleaning operations), by the rigorous segregation of non-radioactive and radioactive materials and by the segregation of radioactive materials according to the type and activity of the radionuclides they contain. Considerations for optimal operating practices and of decommissioning procedures during a design phase for the new facilities or review and change of existing practices at operating facilities can also significantly reduce waste generation rates.

Minimization of Disposal: For radioactive waste that is generated (avoidance is not practicable), the following options can be pursued to minimize the amount of waste requiring disposal:

- Waste can be “decay stored” to reduce its radioactivity. This option can simplify and increase the effectiveness of waste treatment and/or conditioning or it can lead to clearance (see Subsection 3.1) of the waste from regulatory control.
- Clearance can be used to qualify some materials for restricted or unrestricted reuse or recycling (therefore, they are no longer considered waste) or waste can be cleared for disposal as non-radioactive waste. Both or these options can significantly reduce the amount of radioactive waste requiring disposal.

As mentioned on Page 55, the second issue of this Status and Trends report reported on waste minimization in the context of decommissioning and concluded that waste minimization should be an integral part of any decommissioning strategy. It elaborated on the variety of technical, regulatory, economic and social considerations that have to be taken into account for the selection of a decommissioning strategy. It also concluded that most of the factors that have to be considered when preparing the strategic, tactical and technical decisions required to choose an adequate decommissioning strategy are also the main elements used for choosing a waste minimization strategy, which include:

- source reduction,
- prevention of contamination spread,
- recycle and reuse, and
- waste management optimization.

As mentioned on Page 55, the third issue of this Status and Trends described innovative approaches to waste minimization. Notably it discussed material substitution and, in particular, the introduction of polyvinyl alcohol (PVA) based clothing that could lead to dramatic reductions in waste requiring disposal.

This fourth issue considers the link between waste minimization and waste management. Optimization is applied to a waste management "system" while minimization refers to an activity that can positively impact on that system.

Nuclear technologies, including the technologies applied to waste arisings and their management, remain in a dynamic and evolving state. Given the pace of technological advances, it is likely that, within just a few decades, we will be able to reuse, recycle, treat, condition and/or reduce the volume all radioactive materials such that the wastes generated and disposed at various steps of waste management activities might represent only a small fraction of today's waste arisings.

The optimization of a radioactive waste management system is a complex task, with many factors to be taken into consideration. Typically the system may be designed to maximize the value of available resources or facilities or to minimize total cost (or local costs). Other criteria, such as national regulations/policy and waste acceptance criteria for storage/disposal facilities, must also be considered and may tend to direct the waste management system towards or away from specific options.

Relative volumes of different types of waste, availability of disposal options, as well as availability and versatility of technical options for treatment, conditioning, etc., are also important considerations for designing an optimized, integrated waste management system. Minimization of wastes, by not generating them in the first place or minimizing their quantities if they are generated, is an important role of many integrated waste management systems.

Optimization may consider each step or waste stream in isolation and optimize a specific part of the system. This approach, however, may not necessarily optimize the total, or integrated, system. By understanding the interdependencies and interactions between various components of the system, one can often achieve an overall improvement.

By employing "waste minimization" techniques, each step of the waste management system can significantly reduce the total amount of waste destined for disposal. In all cases, this will reduce the down stream waste management resource requirements. In situations where the cost of disposal is high, waste minimization may have the added benefit of large financial savings in disposal costs.

A possible national level (or organization level) LILW minimization strategy applicable to all stages is depicted in Figure 6-1. In order to be effective, the strategy must have strong and visible support at all decision-making levels. If every nuclear worker is aware of the impacts of LILW generation, then reasonable efforts to reduce its generation at source can be accomplished with modest cost. The following discussion summarizes the key aspects and impacts of source reduction programmes, reuse/recycle programs, and volume reduction programmes.

<u>Source reduction (waste avoidance) programmes</u>

Often overlooked, a key method to reduce the overall impact of LILW management is "not to produce the waste in the first place." Traditionally, the biggest gains in source reduction have come from:

- reduction in the number and size of contaminated areas,
- prevention of equipment leaks and subsequent contamination, and
- segregation of clean materials from contaminated materials.

Implementing reasonable efforts to avoid generation of radioactive wastes through source reduction and prevention will have high return on labour investment with low cost implementation.

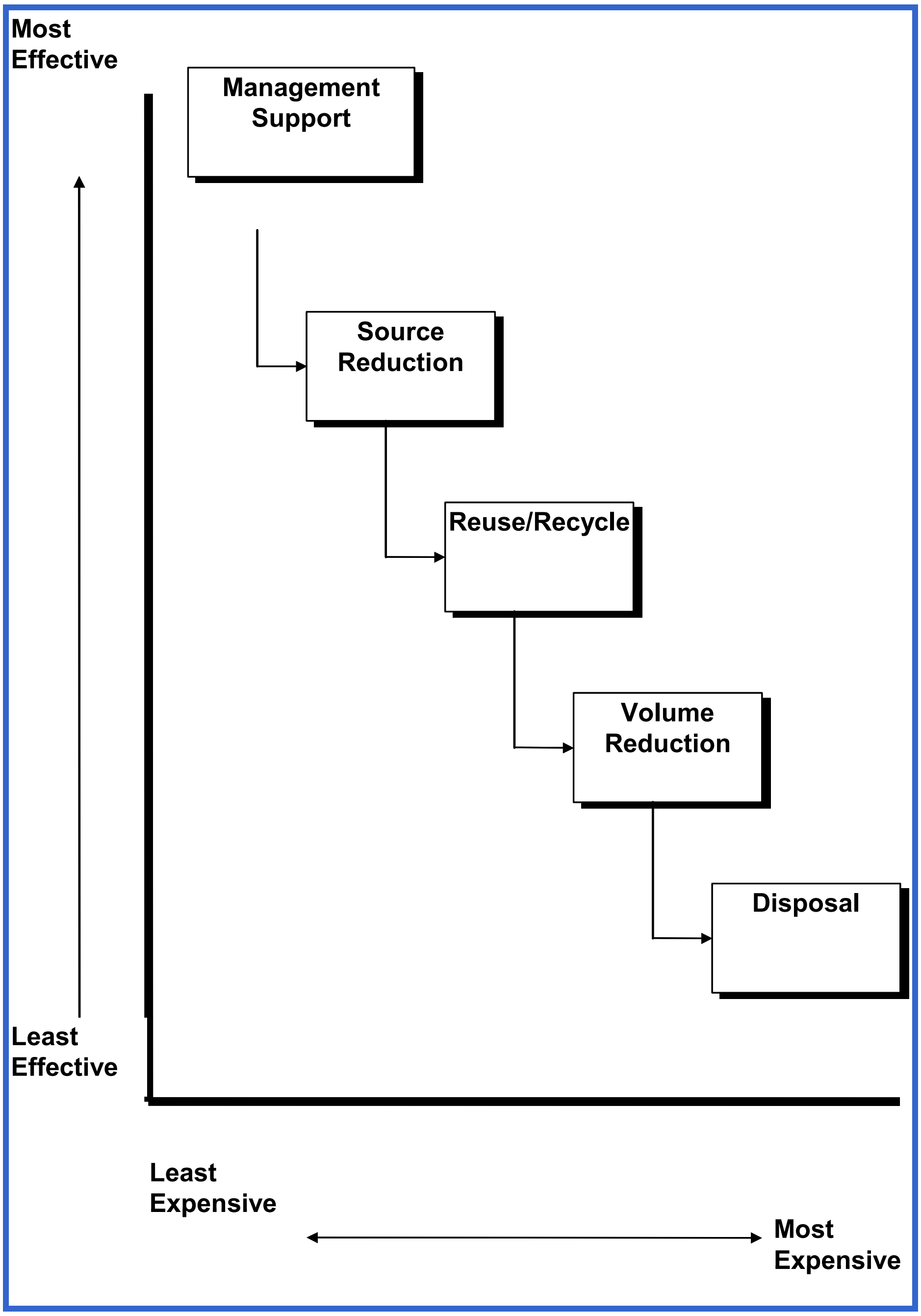

Figure 6-1: Minimization Strategy

<u>Reuse/recycle programmes</u>

If waste generation cannot be avoided, many materials can be removed from the LILW stream through decontamination and subsequent reuse or recycling. For example:

- Waste can be minimized through substitution of disposable materials (such as paper and plastic products) with re-usable materials. The most effective substitution is the elimination of disposable paper/plastic protective clothing and sheeting materials and replacing them with washable, reusable materials.
- Tools and equipment can be decontaminated and reused in either nuclear or non-nuclear applications.
- Wooden scaffolding planks can be planed to remove the contamination, then recycled.

- Miscellaneous metallic objects can be decontaminated, then either reused or recycled as conventional scrap metal.

The initial investment in reusable/recyclable materials is typically offset by a reduction in the purchase, conditioning and disposal costs of disposable alternatives. This represents a high return on investment in terms of reduced waste generation and disposal volumes.

Volume reduction programmes

While source reduction avoids the generation of waste, volume reduction applies after waste has been generated. Once a material has been declared waste (i.e., of no further re-usable or recyclable benefit), a number of volume reduction techniques can be employed, depending on the local availability of technology, to reduce the "as disposed" volume of the waste. Typical methods include compaction, supercompaction, incineration, metal melting, sectioning of bulky objects, etc. New techniques are being developed to handle a wider range of wastes, with further reduction of volumes of waste that needs to be disposed.

Conditioning costs compete against direct disposal costs, therefore, a large reduction of disposed waste volumes can significantly lower unit disposal costs and can extend the operating life of a repository (within the constraints of safety considerations).

The IAEA is currently preparing a new publication that will examine radioactive waste arisings in various nuclear fuel cycles.

6.2 Waste Characterization

Characterization of radioactive waste determines its principal physical, chemical, biological, mechanical and radiological properties with the main objectives of:

- establishing the treatment and/or conditioning needed,
- complying with safety requirements and acceptance criteria for storage and/or disposal facilities, and
- compiling and verifying the inventory of waste storage and/or disposal facilities.

Characterization can be performed at any predisposal stage (subject to the limitations of cost and safety). Historically, it has been a "front end driven" process – the organization in possession of the waste determined the extent to which the waste was characterized. However, lessons learned over the years have determined that characterization should be a "back end driven" process – the organization that will receive the waste determines the extent to which the waste should be characterized by the organization the currently holds the waste [6.3].

Repository operators define acceptance criteria that specify the terms under which waste will be accepted for disposal. Typically, the criteria define the limits of activity for specified radionuclides, external radiation fields, heat generation from radioactive decay, as well as physical and chemical properties such as mechanical strength, limits on free liquids, leachability, limits on chemical and biological hazards, limits on incinerable and pyrophoric substances, etc.

As waste moves along the waste management chain, from generator to disposal facility, each organization that takes possession of the waste will be responsible for verifying the accuracy of characterization data – commonly known as compliance monitoring. Additionally, if the waste is altered via treatment or conditioning, additional characterization may be required. Ultimately, the organization consigning the waste to disposal must provide the final characterization of the packages to be disposed in the repository.

Figure 6-2 gives an overview of a general characterization strategy.

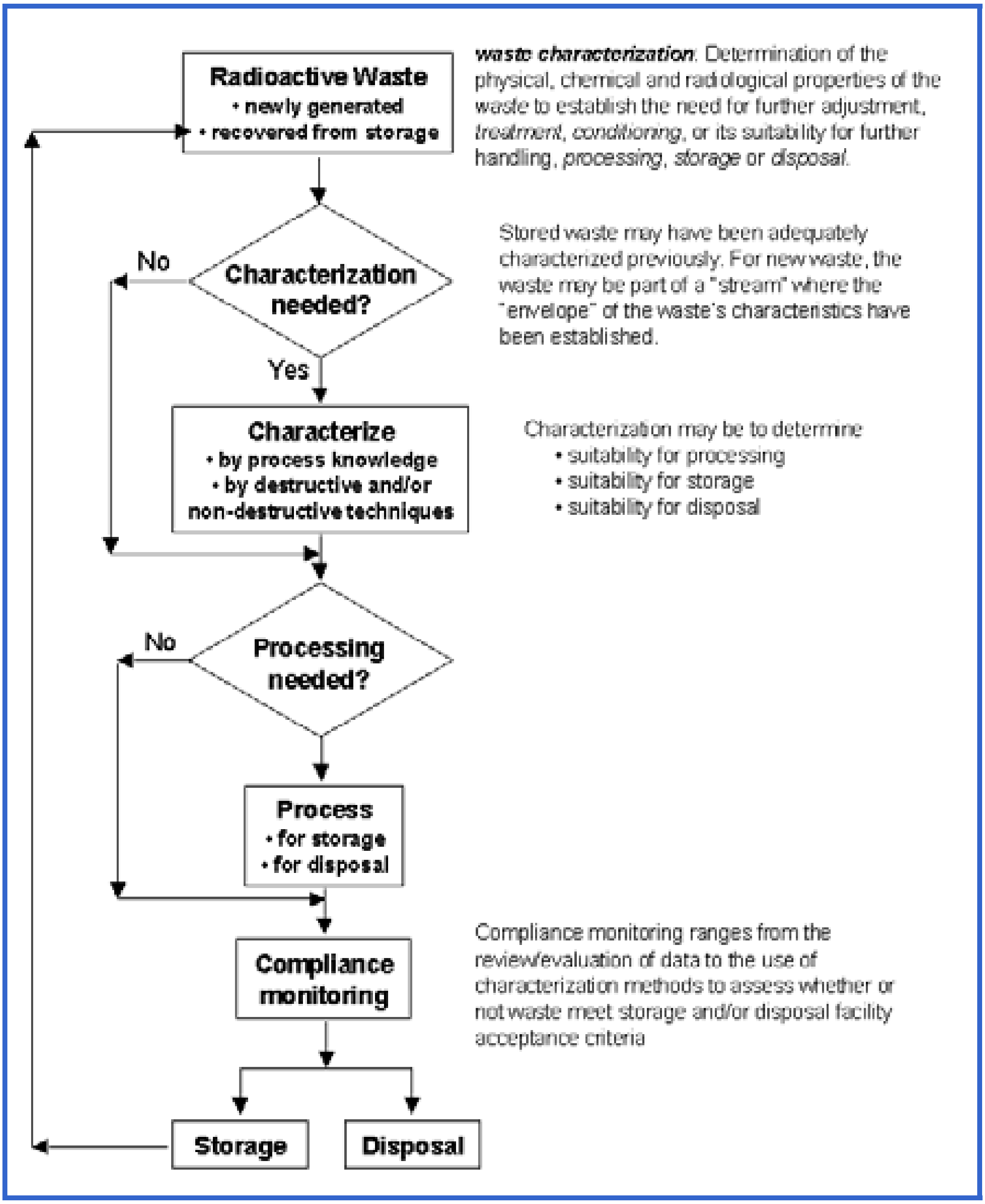

Figure 6-2: General Characterization Strategy

There are two basic approaches to waste characterization:

- all waste in a stream is characterized, or
- a representative sample of waste is characterized.

The first case above is typically applied when there is a cost-effective, non-destructive method for characterizing the waste. For example, all drums in a given waste stream may be subjected to x-ray, gamma-ray and neutron scanners. Additionally, if it is cost effective or deemed appropriate, even costly destructive characterization methods could be applied to every batch of waste if whole batches of waste could be homogenized, sampled and analyzed (typically for liquid waste). Finally, this case typically applies to unique, "one off" waste, where only a relatively small amount of waste (by volume or mass) needs to be characterized.

In the second case, cost and safety considerations could preclude the characterization of all waste in a stream. In this case, representative samples would be taken for characterization. This case typically applies to wastes that are routinely generated, such as nuclear power plant (NPP) operations waste. The principal technical challenge in this case is demonstrating that representative samples have been obtained. Heterogeneous wastes such as contaminated material, gloves, etc., are much more difficult to sample than waste that is homogeneous or that can be readily homogenized. Some non-destructive techniques, such as segmented gamma scanning, are often used to overcome problems associated with heterogeneity [6.4].

Sometimes it may be necessary to calculate, estimate or infer some waste properties from the determination of other properties. For example, a "complete" radionuclide inventory of wastes can be compiled by:

- assaying the easy-to-measure radionuclides (such as gamma-ray emitters) and then calculating or estimating the quantities of difficult-to-measure radionuclides (such as beta- or alpha-emitters), and/or
- measuring the external radiation field on a waste package and calculating the complete radionuclide inventory based on scaling factors that are typically determined by destructive analysis.

The first example above is often used for NPP operations waste. Typically Co-60 measurements are used to estimate the inventory of neutron activation products (such as C-14, Ni-59, Ni-63 or Nb-94) and Cs-137 is used to estimate the inventory of fission products (Sr-90, Tc-99, I-129 and Cs-135) in operations waste.

The selection of destructive or non-destructive techniques, including a combination of their application, depends upon a variety of factors such as:

- routine versus non-routine waste,
- large versus small volume waste,
- homogeneous versus heterogeneous waste,
- easy-to-measure radionuclides with established relationships to hard-to-measure radionuclides (scaling factors determined),
- ability to obtain representative samples,
- ability to cost-effectively assay all packages in a stream, and
- overall cost and safety considerations.

Destructive methods are often used to determine the inventories of pure alpha- and beta- emitters. In those cases, radiochemical analyses are necessary. For raw wastes such as ion exchange resins, evaporator concentrates, highly radioactive liquid wastes etc., individual analytical procedures are often developed for specific radionuclides. Characterization of conditioned wastes often requires an initial dissolution of the waste for before analyses can be carried out. As mentioned previously, for routine waste that have undergone extensive characterization, it is possible to correlate "key", easy-to-measure radionuclides with hard-to-measure radionuclides. This is a significant factor in the characterization of routinely generated LILW waste from NPP operations, where important (from a disposal viewpoint), long lived radionuclides are estimated based on non-destructive measurements of a few gamma-emitters.

Non-destructive methods use spontaneous or induced radiation that is interpreted to estimate the content of one or more nuclides of interest [6.4]. There can be active assays, based on the observation of secondary radiation induced from an external source or passive assays based on natural occurring or spontaneous radiation.

Among active systems, radiography is an important technique, by which waste packages are subject to an intense X-ray field and the attenuated rays are translated in real time to a monitoring system.

Non active systems include gamma scanning and neutron assay systems. Gamma scanning is typically used for characterization of waste drums where the activity distribution is assumed to have an axial symmetry. The effects of radial heterogeneities are minimized by rotating the drum while scanning. This technique utilizes high resolution Ge-Li detectors along the rotating cylinder.

Tomography is a computer technique typically applied in conjunction with both X-ray and gamma assay systems. Tomography can be passive (measures radiation emanating from a waste package) or active (an external radiation field is applied). The processing of signals from multiple access detectors creates 3-dimensional images of a package's contents. Radioactive material is then visualized; not only its location but particle size may also be determined.

Characterization of waste also necessitates a waste tracking system. This system should be integrated from the generator of the waste to the disposal organization, in such a way that all relevant records, samplings, analysis and assays can be tracked backwards and audited from any of the organizations that conduct the different steps of predisposal.

In subsequent issues of this Status and Trends report, examples of existing and emerging waste characterization methods will be presented. The next Subsection describes an innovative approach to characterization in decommissioning activities.

6.2.1 Topical Issue: Innovative Technologies for Characterization of Underground Piping in Decommissioning Projects

The subject of underground and embedded piping relates to more than the piping itself. Many directly related components include fittings, valves, instruments wall penetrations, and hangers. The subject area also includes components connected by piping, such as pumps, sample collection devices, sumps, compressors, and vessels.

Buried pipes transferring contaminated fluids between buildings or tanks were commonly used at nuclear facilities designed and operated in the 1960s and 1970s. However, often there were problems presented by their design features. Typical problems associated with the decontamination and dismantling of those pipes include:

- uncertainties on exact piping routes and system connections due to poor design and (as-built) construction records and modest inspection possibilities,
- inability to distinctly identify the radiological and chemical contaminants because of poor operational records and/or lengthy idle periods between operations or following final shutdown,
- poor accessibility making physical and radiological characterization difficult,
- difficult access to injection points for the use of various decontamination chemicals,
- presence of hard-to-decontaminate deposits, sludge or sediments often due to long dormancy periods and lack of proper maintenance,
- uncertainties on the physical state of the piping walls and the possibilities for ongoing leakage that could render aggressive decontamination undesirable,

- difficult access for disassembly, including preliminary removal of obstacles and removal of segmented pieces,
- harsh working environments due to the presence of tight spaces, likelihood for heat stress, and/or high radiation/contamination levels requiring the use of personal protective equipment,
- inadequate or poorly adaptable technologies for handling, treatment, conditioning and storage/disposal of waste system piping including the management of toxic material such as asbestos insulating materials,
- lack of clearance regulations and measurement technologies for release of decontaminated pipes, and
- possible contamination of nearby components/structures and the soil due to leaking pipes and uncertainties on the extent of peripheral remedial work that may be required.

It should be noted that most of these issues are also relevant to the decontamination and decommissioning of underground tanks and other underground/embedded components. Descriptions of a few innovative and emerging piping characterization technologies are given below. A number of these techniques were developed, deployed and optimized on actual decommissioning operations with funding from the US Department of Energy to cope with the enormous legacy of redundant nuclear facilities in the USA [6.5]-[6.7]. Specific technologies addressed contaminated piping. Costs of these technologies and results from their testing are given in Reference [6.8].

*Pipe Explorer^tm^*

This device is intended for characterization of pipes/drains. It is a pneumatically operated tubular plastic membrane that transports various characterizing sensors (e.g. gamma detectors, beta detectors, video cameras, and pipe locators) into contaminated piping systems. Historically this activity has been attempted using hand-held surveying instrumentation, surveying only the accessible exterior portions of pipe systems (however, there is no way of checking for alpha and/or beta contaminants) or resorting to costly exploratory digging and removal. Various measuring difficulties, and in some cases the inability to measure threshold surface contamination values and worker exposure, and physical access constraints have limited the effectiveness of the traditional survey approaches. An area where Pipe Explorer has been particularly effective is the capability to demonstrate that buried pipes were not contaminated and, therefore, could be left in place or removed using standard removal or demolition techniques. Pipe Explorer was deployed at various decommissioning sites e.g. Mound, Trojan NPP, Crystal River NPP, Idaho National Engineering and Environmental Laboratory [6.9] and CP-5 Decommissioning Project at Argonne National Laboratory [6.10]. Figure 6-3 gives an overview of Pipe Explorer.

*Pipe Crawler^tm^*

Pipe Crawler consists of a wheeled platform on which is mounted an array of thin Geiger-Müller detectors. Crawler is manually transported through pipes using flexible fibreglass rods. It was extensively tested at CP-5 Decommissioning Project [6.10] and Park Township Site. It is described in more detail in [6.11]. The development of a pipe crawler system and the results of a specific application at Savannah River Site are described in full detail in [6.12]. Further experience, costs, strengths and limitations of this system are given in [6.13], [6.14]. Figure 6-4 provides a photo of Pipe Crawler.

Alpha contamination measurements

Direct measurement of alpha contamination inside pipes is difficult because alpha particles have such a short travel range (alpha particles can only travel a few centimetres in air and only a few microns in materials such as aluminum). Therefore, indirect methods are used to measure alpha-emitting radionuclides. The IonSens monitors were used at the United States Department of Energy’s Savannah

River Site in a fuel fabrication facility in late 1998 to measure alpha contamination in pipes that have inaccessible surfaces [6.15]. Detectors based on the Long Range Alpha Detector (LRAD) technology have been developed at the Los Alamos National Laboratory in the USA. The LRAD technology measures alpha contamination by detecting the ions produced in a gaseous medium by alpha particles rather than by detecting the alpha particles themselves. The advantage of LRAD technology is that, unlike conventional detectors, LRAD-based instruments do not need to be in close proximity to the alpha sources to provide a sensitive measurement. Monitors were designed and built especially to detect contamination in pipes [6.16], [6.17].

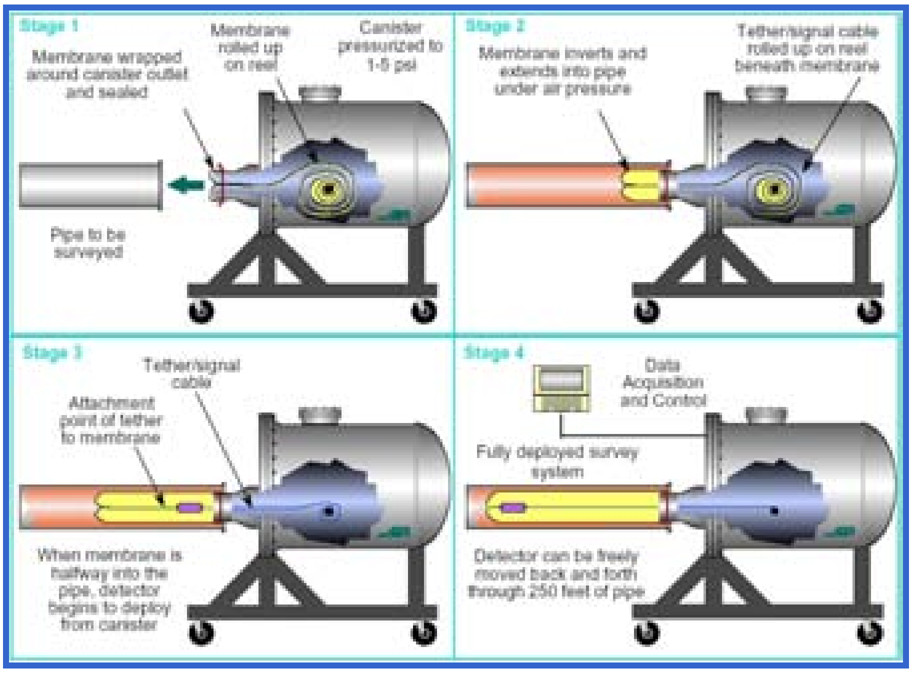

Figure 6-3: Pipe Explorer[tm] Overview
(source http://tech.inel.gov/tech-detail.asp?id=67)

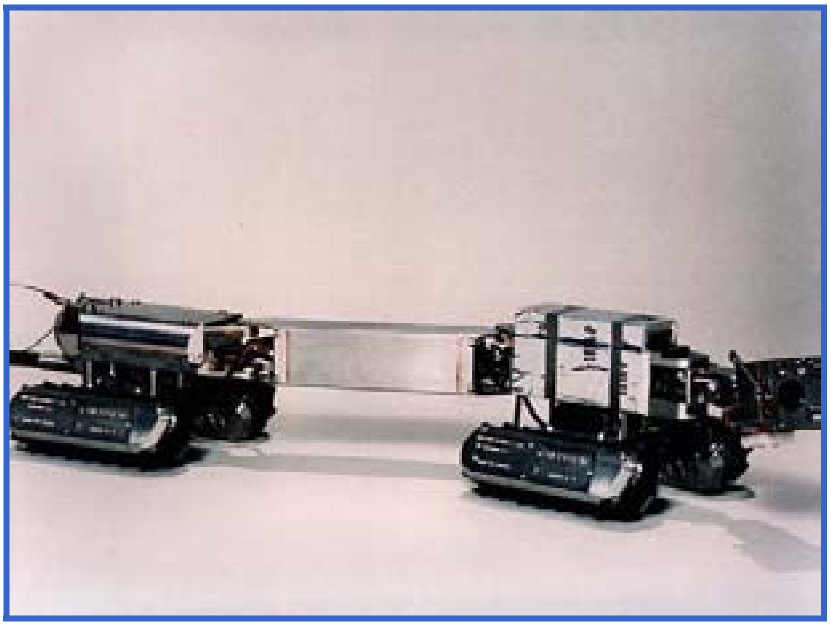

Figure 6-4: Pipe Crawler[tm]
(source http://www.netl.doe.gov/dd/images/photos/html/technologies/characterization/bb11097.htm)

Subsurface contamination measurements

A typical problem with radiological characterization of underground pipes is the possibility that pipes had leaked and contaminated the surrounding soil. An interesting application of innovative technologies to solve this problem is given in [6.18]. During operation of the Brookhaven Graphite Research Reactor, the below grade exhaust air ducts provided passage of the cooling air flowing through the graphite reactor pile to the exhaust stack. Following reactor shutdown, the ducts collected water and were a potential source of contamination to the soils beneath the facility. Thorough subsurface soil characterization was required to determine the location and extent of potential contamination to facilitate appropriate remedial action planning for the below grade facilities and surrounding soils. The innovative technologies included the use of a small Geoprobe to install sampling ports in the soil and beneath the buildings. Components included gas tracers to define the leak pathways, 3-D visualization tools to investigate the data, the In-Situ Object Counting System (ISOCS) for rapid field gamma surveys of soil samples, and BetaScint, for beta surveying of soil samples.

6.3 Waste Processing

The IAEA defines waste processing as [4.12]:

> *any operation that changes the characteristics of waste, including pretreatment, treatment and conditioning*
>
> and also defines the following:
>
> ***pretreatment*: *any or all of the operations prior to waste treatment, such as collection, segregation, chemical adjustment and decontamination***
>
> ***treatment***: *operations intended to benefit safety and/or economy by changing the characteristics of the waste. Three basic treatment objectives are (a) volume reduction, (b) removal of radionuclides from the waste, and (c) change of composition of the waste*
>
> ***conditioning***: *operations that produce a waste package suitable for handling, transport, storage and/or disposal. Conditioning may include the conversion of the waste to a solid waste form, enclosure of the waste in containers and, if necessary, providing an overpack*

In addition to the activities cited in the definition of pretreatment, waste minimization and characterization may also be considered part of pretreatment activities. However, minimization and characterization are dealt with elsewhere in this report (Subsection 6.1 and Subsection 6.2, respectively). For this reason, Subsection 6.3 only deals with treatment and conditioning.

Issue 1 of this Status and Trends report provided an overview of some commonly used methods for liquid and solid radioactive waste treatment and conditioning to facilitate handling, transport, storage and disposal. It pointed out that most common methods for treating LILW include:

- compaction, super compaction, and incineration (solids); and
- chemical precipitation, evaporation, ion-exchange, and membrane separation (liquids).

Issue 1 also indicated that the current, commonly used methods for conditioning LILW include:

- encapsulation / immobilization, e.g., grouting / bituminization, cementation,
- polymerization (solids)
- immobilization, e.g., bituminization, cementation, and polymerization (liquids and “wet solids”, such as ion exchange resins, sludges and slurries)

Issue 1 also provided an overview of partitioning and transmutation in the context of spent fuel reprocessing and briefly discussed the DUPIC Fuel Cycle as a means of dry processing spent Pressurized Water Reactor (PWR) fuel into fuel for use in CANDU reactors.

Issue 2 described innovative approaches for processing LILW, which highlighted the "*zero liquid waste concept*" and the recently developed steam reforming/pyrolysis process, which is based on the THermal Organic Reduction (THOR) technology developed and implemented on an industrial scale by Studsvik Inc. Steam reforming has the capability to process a wide variety of solid and liquid LILW, including spent ion exchange resins, graphite, sludge, oil, etc. New approaches for solid waste treatment and conditioning were also discussed, as well as application of vitrification technology to LILW processing.

Issue 3 provided an overview of Belgoprocess as an example of a waste processing operation. Belgoprocess processes all classes of radioactive waste (LILW-SL, LILW-LL and HLW) resulting from both the nuclear fuel cycle activities and from the production and uses of isotopes in medicine, agriculture and industry. Processing includes incineration, compaction, supercompaction, mechanical and thermal size reduction techniques for solid wastes, flocculation and evaporation for liquid wastes, and encapsulation in one of three possible matrices: cement, bitumen or glass.

The current issue of the Status and Trends provides additional examples of waste processing methods, namely:

- application of membrane technologies to liquid radioactive waste processing – these are mainly technologies developed for water and waste water treatment that have been demonstrated to have application in radioactive liquid waste treatment (Subsection 6.3.1.1);
- application of ion exchange processes for the treatment of radioactive liquid waste, pointing out new developments for inorganic exchangers (Subsection 6.3.1.2); and
- management of organic and/or toxic radioactive waste, a fast developing area that has, to date, not been widely addressed (Subsection 6.3.1.3).

6.3.1 Examples of Waste Processing

6.3.1.1 Membrane Technologies

In recent decades, various membrane separation processes have been developed and utilized in the field of potable water purification and more recently in the treatment of various process and waste liquors [6.19]. The most prominent processes are those utilizing a pressure gradient as driving force. These processes include reverse osmosis, nanofiltration, ultrafiltration, and microfiltration. After development of suitable membrane materials, these processes have been adopted by the nuclear industry as a viable alternative for treatment of radioactive liquid wastes.

Pressure driven membrane separation processes may be considered either as alternatives to existing radioactive waste processing techniques or as complementary additions to existing treatment systems. Some modern systems for radioactive waste processing use a combination of membrane separation and conventional steps. Combined systems produce high quality treated effluents, bearing an acceptable level of residual radioactivity for discharge. The volumes of secondary radioactive waste residues are minimized and they can be suitably conditioned to meet waste form criteria for disposal.

A simplified overview of the common membrane separation methods arranged by the main process driving force and the respective application range is shown in Figure 6-5.

Reduction of waste treatment costs is a major factor for considering membrane separation technology either as replacement for or as an addition to a conventional process. Direct cost comparison is possible in some cases (e.g. membrane treatment versus evaporation), although costs may be dependent on local operating and licence conditions. Some membrane processes, such as ultrafiltration and nanofiltration, can perform treatment functions that are not achievable by any particular conventional techniques, and therefore direct cost comparison is difficult.

Relative cost is an important criterion for a process selection. As an example, Figure 6-6 indicates the relative cost of some desalination technologies, as a function of feed water salt concentration [6.20].

This indicates that membrane technologies such as reverse osmosis or electro dialysis are not cost effective at very low ionic strength (where ion exchange is less expensive) or at very high salt concentrations (where distillation (evaporation) is less expensive), but are suitable for the range of feed waters in between these extremes.

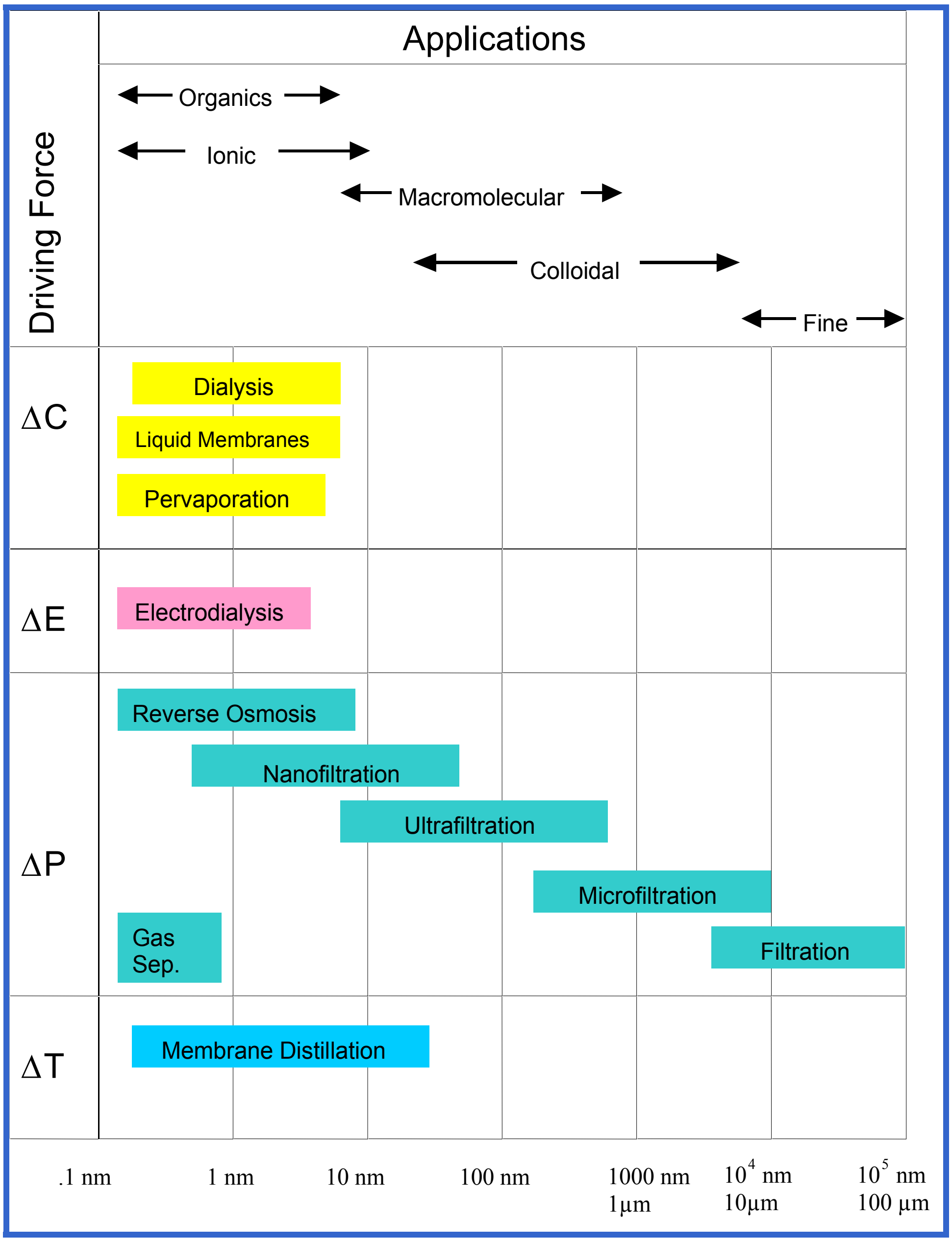

Figure 6-5: Typical Membrane Separation Methods

ΔC=concentration, ΔE=electrical potential, ΔP=pressure, ΔT=temperature

The overall performance of a membrane based separation process depends upon the characteristics of the membrane, the feed solution being treated and the general operating practices that are employed. As each application of membrane technology in a nuclear plant or elsewhere is unique due to specific local conditions, different processing objectives and various other factors, the membrane systems used vary from application to application [6.19].

Membrane systems are rarely acquired as "off-the-shelf" items and should be designed, and then built, only after extensive on site testing for each specific application. Selection of proper membrane materials and membrane module configuration is a prerequisite for the successful application of a membrane system.

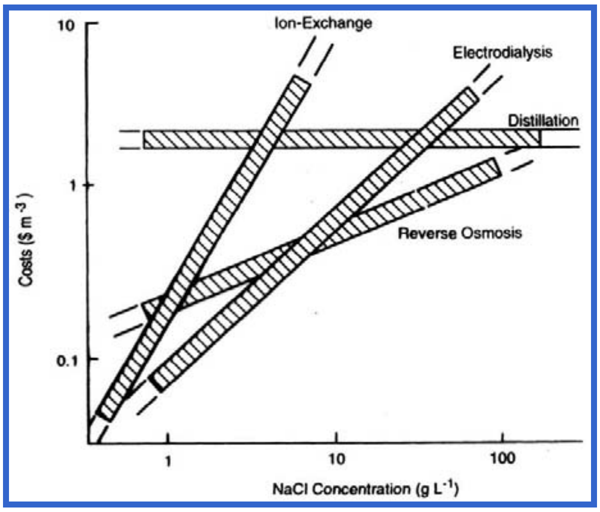

Figure 6-6: Water Desalination Costs as a Function of Salt Concentration

Pressure driven membrane processes are now well established in the nuclear industry. Other membrane separation methods that use electrical potential, concentration, or temperature gradient as the process driving force are either in use or under various stages of development. While some of these have been proven and utilized in various industries, they are not yet technologies of choice for processing liquid radioactive wastes. However, some of these emerging membrane methods are under rapid development. Results of these efforts could become technically significant in the future.

6.3.1.2 Ion Exchange Technologies

Ion-exchange is one of the most common and attractive treatment methods for liquid radioactive waste [6.21]. It is a well developed technique that has been employed for many years in both nuclear and non-nuclear industries. Organic ion exchange resins are typically used to control the water systems chemistry at NPPs for minimizing corrosion or degradation of system components and to remove radioactive contaminants. Organic resins are also used in a number of chemical decontamination or cleaning processes for regeneration of process water by reagent and radionuclide removal.

In the past decade, inorganic ion exchange materials have emerged as an increasingly important tool to replace or complement conventional organic ion exchange resins, particularly in liquid radioactive waste treatment and spent fuel reprocessing applications. Inorganic ion exchangers often have the advantage of much greater selectivity than organic resins for certain radiologically important species such as cesium and strontium.

Although inorganic ion exchange materials are playing an increasing role in the selective removal of specific radionuclides, organic ion exchange resins continue, globally, to represent the dominant form of ion exchange waste material. This is largely because organic ion exchange has been proven to be reliable and effective for control of both the chemistry and radiochemistry of water coolant systems at NPP and also for processing some liquid radioactive waste. In a number of cases, the organic resins cannot be replaced by inorganic ion exchangers for specific physical and chemical reasons.

A general comparison between organic and inorganic ion exchangers is given Table 6-1 [6.21]. Following the table is an overview of the factors to consider for ion exchange.

Table 6-1: General Comparison of Organic and Inorganic Ion Exchangers

	Organic exchangers	Inorganic exchangers	Comments
Thermal stability	fair-poor	good	Inorganic specially good for long term
Chemical stability	good	fair to good	Specific organics and inorganics are available for any given pH range
Radiation stability	fair-poor	good	Organics very poor in combination with high temperature and oxygen
Exchange capacity	high	low to high	Exchange capacity will be a function of nature of the ion being removed, its chemical environment and the experimental conditions
Selectivity	available	available	For some applications, such as cesium removal, inorganics can be much better than organics due to greater selectivity. Ion selective media are available in both organic and inorganic forms
Regeneration	good	uncertain	Most inorganics are sorption based which limits regeneration
Mechanical strength	good	variable	Inorganics may be brittle or soft or may breakdown outside limited pH range
Cost	medium to high	low to high	more common inorganics are less costly than organics
Availability	good	good	Both types are available from a number of commercial sources
Immobilization	good	good	Inorganics can be converted to equivalent mineral structures, organics can be immobilized in a variety of matrices, or can be incinerated
Handling	good	fair	Organics are generally tough spheres, inorganics may be brittle and angular particles are more friable
Ease of use	good	good	If available in a granulated form both types are easy to use in batch or column applications

Factors to consider for applying ion exchange to process radioactive waste

Waste Characteristics

Ion exchange is generally suited for treatment of aqueous liquids satisfying the following criteria:

- For column use with downward flow of liquid, the concentration of total suspended solids in the waste should be low, normally less than 4 mg/L, to prevent fouling of the ion exchange media by the solids filtered out by the ion exchanger bed.
- The waste should have a low total dissolved salts (TDS) content, normally less than 1 to 2 g/L, to prevent rapid exhaustion of the ion exchange capacity. When highly selective ion exchange materials are used the TDS can be up to several hundreds of g/L.
- Radionuclides should be present in a suitable ionic form. Adjustment of the solution pH is often sufficient to convert a radionuclide into species that can be removed by ion exchange.
- Generally the waste should contain only very small amounts of organic contaminants. Some compounds, such as oils and greases, if present as a separate phase, will result in severe fouling of the ion exchange media and loss of ion exchange capacity. Others,

such as certain organic solvents, may cause physical decomposition of organic ion exchange media.

Selection of an ion exchanger and a treatment process

A wide range of ion exchange media is now available, from low cost naturally occurring organics (such as coals and peat) and inorganics (such as clays and natural zeolites) to expensive synthetic organics and inorganics engineered to remove specific ions.

The selection of appropriate media depends on the needs of the system. Higher cost ion specific exchangers may be a better choice if the extra cost of the media is more than offset by the reduction in the total cost for treatment and subsequent storage/disposal of the spent media.

The ion exchange media must be compatible with the chemical nature of the waste (such as pH and the type of ionic species present), as well as the operating parameters, notably temperature and pressure.

The total radioactivity content of the waste should be considered in the selection of the ion exchange process. Concentration of the radioactivity onto the ion exchanger can greatly increase (by many orders of magnitude) the radiation fields surrounding the ion exchange. The radiation levels can also affect the stability of the ion exchange media, which is a concern for long term storage and disposal.

Ion exchange application techniques

Ion exchange processes can be implemented in a variety of ways, including batch operation, columns, continuous loops, and as part of, or in combination with, membrane processes. Each technique has features that make it more or less suitable for specific applications [6.21].

Ion exchange regeneration options

In theory, the ion exchange process is reversible. Most ion exchange media can be regenerated by using an appropriate strong acid (such as HNO_3) for cation media or alkali (such as NaOH) for anion media, to replace the bound contaminant ions on the media and restore the media to its original chemical form. The life of media can be extended, by regeneration, thus saving on costs of new media and disposal of old media. The fact that regeneration does typically restore ion exchange capabilities only to 90% is an important factor for nuclear grade ion exchangers, because nuclear grade quality is maintained only until the first regeneration. On top of that, regeneration is not practiced for radioactive systems since the concentrated acid and caustic regeneration solutions are often more difficult and costly to treat than the money saved by lower media usage.

Integration with other waste treatment systems

Ion exchange is frequently employed in combination with other liquid treatment processes, usually as a final or "polishing" step. For example, conventional filtration can be used to remove particulate "crud", and the filtrate then treated by ion exchange. Total dissolved solids may be reduced by chemical precipitation and the clarified liquid can then be polished by ion exchange.

Management of spent ion exchange materials

Spent ion exchange materials represent a special type of radioactive waste, posing unique problems in the selection of treatment options since they often contain high concentrations of radioactivity because of the function that they fulfil. In the past, these materials were often disposed of in drums or boxes or as disposable ion-exchange columns without treatment. In some operations, the resins were sluiced from columns and stored in underground tanks as a bed settled in water, pending future disposition.

Selection of treatment options for spent ion exchange materials must consider the physical and chemical characteristics of the material. Basically, there are two main methods for treatment of spent organic ion exchange materials: (1) destruction of the organic compounds to produce an inorganic intermediate product that may or may not be further conditioned for storage and/or disposal and (2) direct immobilization producing a stable end product.

The immobilization matrices currently used for spent ion exchangers are cement, bitumen and some polymers. In some countries "high integrity containers" are used for storage and disposal of spent ion exchange media, without incorporation into a solidification matrix. Most of the processes using the above matrices are performed on an industrial scale and are described in detail in many publications. Table 6-2 summarizes the general advantages and limitations of these immobilization matrixes [6.21].

It should be noted that the specific application of a matrix for a given waste must be evaluated on an individual basis. Pilot level studies may be required to determine the optimum waste loading and matrix composition. This is especially true for cements and some polymers, where trace amounts of certain materials within the wastes may adversely affect the properties of the product (for example, preventing the cement or polymer from solidifying, or producing a product of poor quality).

Table 6-2: Summary Comparison of Immobilization Processes

Matrix	Advantages	Disadvantages
Cement	- Material is readily available and not expensive; - Compatible with wide range of materials; - Excellent radiation stability; - Non flammable product; - High pH results in good chemical retention most of radionuclides.	- Swelling of organic bead resins may cause cracking of matrix; - Waste loading can be low, volume of final waste form is greater than original waste volume; - Moderate leach resistance for many radionuclides, such as Cs.
Bitumen	- Good leach resistance; - All water in waste is removed by process resulting in good waste loadings.	- Waste form will soften at moderate temperatures; - Requires container to maintain structural stability; - Organic bead resins may swell and compromise waste form if prolonged contact with water; - Organic waste form may be flammable and subject to biodegradation; - Lower radiation stability than cement.
Polymers	- Wide variety of polymers available; - Good leach resistance for many polymers;	- Generally more expensive than bitumen or cement; - Polymerization reaction can be affected by trace materials in the wastes; - Lower radiation stability than cement.
High integrity container	- Simple and inexpensive to operate and handle; - Steel containers have excellent radiation stability.	- Relies entirely on container integrity; - Not accepted in all jurisdictions; - Polymer containers can have low radiation stability.
Vitrification	- Glass waste form has excellent radiation stability and leach resistance; - Good volume reduction in process.	- High temperature process; - Expensive to operate.

In addition to the technical factors outlined above, other factors, such as national standards and waste acceptance criteria for storage and/or disposal facilities, must also be considered. The evolution of performance-based disposal facility acceptance criteria now requires that spent ion exchange materials meet specific quality requirements prior to disposal. Where disposal facilities exist, waste acceptance criteria define the quality of waste forms for disposal and, therefore, will sometimes define appropriate treatment options.

6.3.1.3 Organic and Chemically Toxic Waste Processing

Organic waste forms a significant fraction of the radioactive waste produced at many nuclear facilities, including power reactors, nuclear fuel cycle facilities, research centres and medical facilities. The organic waste may be in a solid, liquid or, less commonly, a gaseous form.

The organic nature of the waste often introduces additional hazards not seen with inorganic waste, such as susceptibility to radiolysis and biodegradation, flammability, volatility, chemical toxicity and inherent biological hazards. This results in special requirements and considerations for storage, treatment, conditioning, packaging and disposal for this waste. These requirements and considerations vary depending on the waste and the selected treatment/conditioning process, and are generally captured in waste acceptance criteria for the treatment, storage and disposal facilities.

Organic radioactive waste has diverse characteristics that require careful consideration when selecting waste management options. In order to deal effectively with the potential hazards associated with organic radioactive waste, an overall strategy should be developed, with the objective of stabilizing the organic waste and eliminating or mitigating (removing or reducing) the potential hazards. This will often include treatment processes, which may change the form and properties of the original waste.

Processing of organic waste is a fast developing area. Different treatment and conditioning options are under investigation, development and broad practical application in several Member States. There are a wide variety of treatment and conditioning techniques available for organic wastes (summarized in Table 6-3) [6.22]. The selection of an appropriate management strategy and treatment/conditioning technique for a given waste is often a complex process. Economics, local regulations and perceptions, versatility to treat a range of wastes, quantity of secondary waste generated and technical performance of the process require consideration.

The primary goal of any treatment or conditioning is to produce a waste form that is physically and chemically stable with limited mobility of the radionuclides and is suitable for all subsequent phases of waste management, including storage, transport to a repository, and ultimately disposal. This can be done by destroying the organic structure (such as by incineration or other oxidation process to produce an inorganic residue), and/or by encapsulation in a suitable matrix and container. The effects of biodegradation need particular attention if storage of the untreated waste is included as part of a waste management strategy. The effects of slow degradation of some treated and conditioned organic waste over the long term also needs to be considered if storage prior to disposal is included as part of the waste management strategy.

6.3.2 Collection and Dissemination of Radwaste Processing Information by the IAEA

The IAEA's Net Enabled Waste Management Database (NEWMDB, see Subsection 11.1) is used to collect information about waste processing facilities and information about waste treatment and/or conditioning methods.

The first two data collection cycles for the NEWMDB took place from July 2001 to March 2002 and July 2002 to January 2003, respectively. The second collection was actually an extension of the first since participation in the first cycle was low. At the conclusion of the second cycle, 36 Member States had made submissions to the NEWMDB. The participating Member States had 70% of the operating nuclear power plants world wide and, therefore, the inventories they reported represent most of the world's radioactive waste (within the scope of the data collection). The results of the first two cycles were published on the Internet and on CD ROM. Reports are accessible on line or can be ordered from the NEWMDB web site [2.3]. The third data collection was held March to July 2004 – 42 Member States had their submissions published. The results can be accessed via the NEWMDB web site.

Table 6-3: Potential Applicability of Techniques

Technique	Waste Types							
	Rubber / plastic	Cellulose	IX Resins	Biological material	Mixed solids	Lubricants	Organic Solvents	Other liquids
Non-destructive techniques								
Drying and evaporation	N	Y	Y	Y	Y		Y	Y
Distillation	N	N	N	N	N		Y	
Physical conditioning			N	N	Y	N	N	N
Decontamination	Y	Y	N	N	Y	Y	Y	
Absorption	N	N	N	N	N	Y	Y	Y
Compaction	Y	Y	Y		Y	N	N	N
Direct immobilization	Y	Y	Y		Y	N	N	N
Destructive Techniques								
Incineration	Y	Y	Y	Y	Y	Y	Y	Y
Pyrolysis / steam reforming	Y	Y	Y	Y	Y	Y	Y	Y
Alkaline hydrolysis (TBP/OK)	N	N	N	N	N		Y	
Vitrification	Y	Y	Y	Y	Y			
Plasma treatment	Y	Y	Y	Y	Y	Y	Y	Y
Molten salt oxidation	Y	Y	Y	N	Y		Y	
Electrochemical treatment	N	N	N	N	N		Y	Y
Direct chemical oxidation							Y	
Acid digestion	Y	Y		Y	Y		Y	
Wet oxidation			Y			Y	Y	Y
Advanced oxidation	N	N	N	N	N			Y
Supercritical water oxidation	Y	Y	Y		Y		Y	
Biological treatment		Y	Y	Y				
Thermo-chemical treatment			Y	Y		N	N	N
Microwave treatment			Y	Y				Y

Key: Y - Known or likely to be appropriate N - Not an appropriate technique Blank - Unknown or possible

6.4 Waste Storage

The IAEA defines storage as [4.12]:

> *the holding of spent fuel or of radioactive waste in a facility that provides for its containment, with the intention of retrieval*
>
> *Storage is by definition an interim measure, and the term* ***interim storage*** *would therefore be appropriate only to refer to temporary, short-term storage when contrasting with the longer-term fate of waste. Storage as defined above should not be described as interim storage".*

The purpose of this subsection is to discuss issues related to radioactive waste storage, not interim storage. It is realized, however, that not all countries follow the IAEA's recently stated definition in a consistent manner. This subsection may contain information about radioactive waste storage in some Member States that use the term interim storage for storage. Within this subsection, any and all references to interim storage are to be taken to mean storage, per the IAEA definition.

The first issue of the Status and Trends report gave a very general overview of radioactive waste storage and noted an "increasing reliance" on storage world wide due to limited progress in implementing disposal. The second issue highlighted storage facilities for spent fuel and reprocessing waste and noted that storage is an effective tool for reducing the radioactivity of waste prior to additional handling or disposal. The third issue provided examples of radioactive waste storage in the Netherlands, the UK and Germany. It also included a topical subsection on long term storage.

In this issue of the Status and Trends report three examples of combined storage/disposal facilities are described, as follows:

- Bulgaria: While Bulgaria has nuclear power generation, the facility described was designed for waste generated in industry, medicine, research and education.
- Finland: Finland has nuclear power generation and the combined storage/disposal facility was designed to handle waste from both nuclear power and non-power applications.
- Norway: Norway does not have nuclear power generation and, as such, the facility described is for the management of non-power application waste.

As a topical issue, an update of long term storage capacities and requirements is presented. This update discusses public attitudes towards disposal, which have resulted in delays in repository implementation and the subsequent prolongation of storage times for radioactive waste and spent fuel.

6.4.1 Examples of Radioactive Waste Storage

6.4.1.1 Examples of Combined Storage/Disposal Facilities

Novi Han (Bulgaria)
based on input provided by Mr. Georgi Simeonov
Bulgarian Nuclear Regulatory Agency (NRA)

The Novi Han repository is located Southeast of Sofia, Bulgaria, near the village of Novi Han. The main purpose of the facility is to dispose of radioactive waste from industry, medicine, research and education. However, in addition to a near surface repository, the Novi Han facility includes a waste storage facility for low level, short lived liquid waste (Bulgarian waste classification, see Subsection 3), mainly derived from the operation of the repository.

The storage facility consists of 4 tanks of stainless steel type 1X18H9T of 4 mm thickness, and only one of them is filled. The tanks are installed in a reinforced concrete cage (5.7m x 7.4m x 4.3m) on concrete supports 0.5 m over the cage floor. The facility is totally underground. The waste water they contain could be discharged into the environment after decay storage or sorption treatment to meet the release limits for discharge to the environment.

The Novi Han facility also has above ground storage facilities for unconditioned low and intermediate level short and long lived radioactive waste (Bulgarian waste classification, see Subsection 3). The capacity is ~470 m^3; ~¾ of this capacity has been used. The storage units consist of:

- 11 standard railway containers with dimensions ~6.0m x 2.4m x 2.4m with a total storage capacity of ~375 m^3. They are designed for storage of smoke detectors in transport packages, solid radioactive waste and spent sources with low specific activity that do not require additional biological shielding.
- 6 waterproofed concrete receivers with walls from 20 to 40cm thick and total volume ~75m^3, designed for storage of spent sources in transportation packages that require additional shielding for ionizing radiation.
- 6 waterproofed cylindrical (1.82m diameter x 2.20m height), reinforced concrete containers with 20cm thick concrete walls. They are designed for storage of high activity gamma irradiator sources in transport packages.

The railway containers and the reinforced concrete containers are located on concrete pad constructed on a draining sand base. A temporary site with an 80 m^2 surface area, with a protection shelter, has also been constructed, for storing very low active waste (Bulgarian waste classification, see Subsection 3) in 200 L drums.

Design and commissioning of modular, reinforced concrete containers for storing Ra-226 sources and neutron sources is under implementation.

Olkiluoto VLJ-Repository (Finland)
based on input provided by Ms. Kaisa-Leena Hutri
Finnish Radiation and Nuclear Safety Authority (STUK)

The low level and intermediate level wastes (Finnish classification – see Section 3) produced at the Olkiluoto nuclear power plant are first gathered into buffer storage and then transported to the final repository for operational waste, the VLJ repository. The repository is located about one km away from the power plant.

The planning of and siting studies for the VLJ repository started in 1980. The Radiation and Nuclear Safety Authority (STUK) granted the construction permit for the repository in 1988. The operating licence was issued by the Government and disposal commenced in 1992. The operational license for the VLJ repository also allows disposal of small amounts of non-nuclear power radioactive waste that is produced in industry, hospitals and research institutes, the called “small user waste” (Finnish waste classification, see Section 3).

The repository facilities lies at a depth of 60 - 100 m in the bedrock having separate silos for low level waste and intermediate level waste (Finnish waste classification, see Section 3). In addition to the two disposal silos, there are two caves at repository depth. One of them is used for research purposes and the other is used to store the “small user waste”, which has been transported there since 1997. An agreement exists between the power company (Teollisuuden Voima Oy) and the Finnish government for the storage of packages of small user waste in the cave until they can be disposed in the VLJ repository. STUK regulates all storage and disposal activities in the VLJ facility.

Himdalen (Norway)
based on a paper by [6.23] and personal communications with Ms. Anita Sørlie
Norwegian Radiation Protection Authority (NRPA)

In March 1999, the Norwegian Radiation Protection Authority (NRPA) gave the Institute for Energy Technology (IFE) permission to start operation of the Himdalen facility for the storage and disposal of low level and intermediate level radioactive waste (Norwegian waste classification, see Subsection 3). Norway does not have any nuclear power plants. The radioactive waste is generated from the operation of the IFE's two research reactors, IFE and other research institutes, hospitals and the oil industry. NORM waste (see Subsection 4.2) was received at Himdalen up to 1996. After 1996, NORM waste has been stored at coastal bases operated by oil companies. The total amount of NORM waste received in Himdalen is about 70 tonnes.

The process to find a repository for all of Norway's waste was started in 1989 by a governmental committee. The committee looked into disposal options and possible sites. In 1992, an impact assessment was performed for three sites and Himdalen was selected as the recommended site. In 1994, Parliament decided on further site investigations at the Himdalen site but it was also decided that Himdalen should be a combined storage and disposal facility. Some Plutonium (Pu) bearing waste is to be stored during operation of the facility. At time of closure, a decision will be made to either remove the Pu bearing waste or to encase it in concrete. The preceding statement is significant in that there is no "*intention of retrieval*" as specified in the IAEA's definition for storage. This raises an important issue – should the definition of storage also include the intention of converting a storage facility to a disposal facility since Himdalen may not be the only case worldwide where a storage facility may be converted to a disposal facility [6.24], [6.25].

6.4.2 Topical Issue - Update: Long Term Storage

High level waste and LILW-LL have been stored safely for several decades. However, in many countries storage may have to be continued for much longer periods before disposal can be implemented. At recent IAEA Conferences in Córdoba, Spain (2000) [3.10] and Vienna, Austria (2002) [6.26] concern has been expressed on the safety of long term storage for radioactive waste.

The proceedings of the Vienna Conference stated:

> "Long term surface storage, as opposed to the final disposal of radioactive waste and spent nuclear fuel, is becoming a reality in many countries. This is occurring for various reasons, including:
>
> - delays in final repository programmes;
> - lack of resources;
> - uncertainties about whether spent fuel should be considered a waste or a resource;
> - lack of public acceptance of disposal;
> - lack of political will to proceed with disposal.
>
> It was concluded that, in the long term, surface storage is unsustainable because of the need to maintain institutional control to guarantee the safety of the storage facility".

Similar conclusions were reached at the International Conference on Storage of Spent Fuel from Power Reactors that was held in Vienna in 2003 [6.27]. There is technical consensus that the present technologies for spent fuel (SF) storage provide adequate protection to both people and the environment. Wet and dry storage are proven technologies, with, to date, longer experience for wet storage compared to dry storage. However, there is continued pressure for further improvements and efficiencies as anticipated SF volumes and storage duration increase and reactor fuels evolve (e.g., higher burn up, higher initial enrichment, MOX fuels, modified cladding). It is therefore essential to investigate not only fuel behaviour during long term storage, but also materials, equipment, installations, procedures and sites used for safe spent fuel storage.

Long term storage of SF requires social stability to maintain institutional control. Storage is a necessary phase of SF management, in which the issue of public trust must be addressed. Since perpetual storage is not feasible for periods extending over the hazardous lifetime of the radioactive isotopes, there is no alternative to disposal over the long term. In addition, it is important to communicate to stakeholders that there is no credible end point other than disposal. When elaborating on strategies for storage, issues of retrievability and transport need to be also considered.

An "IAEA Overview of global spent fuel storage" presented at the Conference indicated [6.28]:

- Worldwide, the SF generation rate, now at about 10 500 tHM[3]/year, is expected to increase to about 11 500 tHM/year by 2010. As less than one third of the fuel inventory is reprocessed, about 8 000 tHM/year on average will need to be placed into storage facilities.
- At the beginning of 2003, about 171 000 tHM of SF were in storage facilities of various types. Most of this SF is under water, but dry storage is becoming a commonly used technology with more than 12 000 tHM currently stored in dry storage facilities worldwide.
- The total amount of SF cumulatively generated worldwide by the beginning of 2003 was close to 255 000 tHM. Projections indicate that the cumulative amount generated by the year 2010 may be close to 340 000 tHM. By the year 2020, the time when most of the presently operated nuclear power reactors will be close to the end of their licensed operation life time, the total quantity of spent fuel generated will be approximately 445 000 tHM.
- Various types of wet and dry storage facilities are operating in Member States with nuclear power plants (Table 6-4). Early in 2002, the global world storage capacity was about 243 000 tHM, with the bulk of storage capacity at reactor pools with 163 000 tHM. Member States operating nuclear power plants actually are or were increasing their existing storage capacity by re-racking their at reactor (AR) storage pools with high-density racks, by implementing burn up credit or by commissioning away from reactor (AFR) storage facilities.

Table 6-4: Capacities of Operating Spent Fuel Storage Facilities (kilo-tHM)

Region	AR	AFR wet	AFR dry	Total
West Europe	28.3	32.3	11.3	71.8
East Europe	11.9	20. 8	1.5	34.2
America	94.7	1.7	8.5	104.8
Asia & Africa	27.9	3.3	1.7	33.0
Total	162.8	58.1	23.0	243.8

Status 1 January 2002

3 tonnes heavy metal

- The storage capacity of new facilities, under construction in the various regions, are shown in Table 6-5. The total capacity is 24 000 tHM with 17 500 tHM as dry storage. This indicates that AFR dry storage is getting more and more preference.

Table 6-5: Capacities of Spent Fuel Storage Facilities under Construction (kilo-tHM)

Region	AFR wet	AFR dry	Total
West Europe	3.0	1.0	4.0
East Europe	3.0	8.9	11.9
America		6.8	6.8
Asia & Africa	0.5	0.8	1.3
Total	6.5	17.5	24.0

Status 1 January 2002

- The global world storage capacity is about 244 000 tHM, and thus exceeded, by about 73 000 tonnes, the capacity needed by 1 January 2003. Globally all types of storage facilities have excess capacity available. On a worldwide basis, the spent fuel arising will fill the existing storage facilities and those under construction by around the year 2017, if no other new additional facilities will be built by that time. However, there is no reason to believe that no new construction projects for storage will be launched. Consequently, a storage shortage is not expected globally.

The issue is not about whether or not there will be a shortage of storage capacity for SF but, instead, it is about how long waste and/or spent fuel should be stored in the context of safety, active control and cost. The waste that exists now must be dealt with in a way that respects the basic principles of protection of human health and the environment. Action is needed to ensure that the management of growing quantities of radioactive waste and SF in storage facilities do not become an “undue burden” to future generations. Furthermore, after the events of 11 September 2001, the possible vulnerability of surface storage facilities to terrorist attack has also highlighted the need to address the issue of long term surface storage.

In considering public attitude, a panel of international experts [6.29] indicated that storage facilities tend to excite less public opinion than disposal facilities. For several reasons, there may appear to be less opposition to siting or expanding a storage facility compared with a disposal facility. It is well established that the level of acceptance of new or expanded storage facilities is greater in communities that have lived alongside nuclear installations for many years - often because it is just a continuation of existing practice. Establishing a disposal facility is a process with many decision points, any one of which can lead to rejection - there are generally fewer decision points in the process of expanding existing storage facilities. Storage is understood to be an intermediate step in the management of wastes and disposal is permanent - perhaps another reason why storage appears to enjoy greater acceptance.

Familiarity with the management of nuclear materials, confidence in safety and employment opportunities can foster community acceptance of storage facilities in communities where nuclear installations already operate. However, this does not mean that concern is not voiced when a proposal is made to expand an existing facility or build a new facility. Acceptance is mostly conditional upon the storage facility being a temporary installation, not the final destination for the wastes; the option of perpetual storage seems to receive little acceptance.

The question of facility maintenance and control was also considered by the experts. Maintenance is easier on the surface than underground, but institutional controls cannot be guaranteed for the period that the wastes remain hazardous. Since adequate protection of humans and the environment will continue only as long as maintenance is continued on storage facilities, and since some of the radioactive material in storage will remain hazardous for many thousands of years, maintenance — or institutional control — would be required for such periods of time or until permanent disposal is implemented. A review of world history reveals that turmoil and change usually occur in much shorter periods of time and therefore that it is unlikely that any societal infrastructure currently in place or envisaged would last for the time period needed.

Additionally, the experts discussed the following topics:

- *Politics and Ethics*: It is clear that the issue of whether to pursue long term storage or dispose of radioactive waste is not one that is solely technical. Other factors of a social, political, economic, and ethical nature are also very relevant. It is equally clear that these factors do not all influence the debate in the same direction. For example, current societal opinion, although not uniform, does not appear to be strongly in favour of disposal. This results in *de facto* continued storage on the surface, since it is an exception to find a community that supports the development of a disposal facility in its midst. Political considerations put a great deal of weight on societal opinions since they affect the way the electorate votes. Although there are good reasons to favour disposal, they do not provide a strong political driving force towards it.
- *Economics*: If a fund exists to internalize disposal costs, there is an economic argument for proceeding with disposal, but if it does not exist the capital cost of a disposal facility can result in economic considerations favouring the continuation of storage. Given that discounted costs have large uncertainties over periods exceeding one generation, and given the inherent uncertainties regarding future disposition of the wastes, it is not clear how the costs for long term storage should be internalized.
- *Safety*: With respect to safety, there are two conflicting arguments. The fact that safe surface storage requires ongoing inspection and maintenance is a strong argument for underground disposal since at some point in the future discontinuance of the present infrastructures that provide for such inspection and maintenance must be expected. The main contradictory argument is the claim that the ease of corrective action in surface facilities can contribute to an improved level of safety assurance.

To further address concerns about long term storage, increased emphasis has been placed on IAEA projects concerned with the safe storage of radioactive waste. A draft Safety Guide “Storage of Radioactive Waste” is being written to incorporate guidance for long term storage and to provide regulators and operators with separate guidance for small and large storage facilities [6.30]. Consultancies and technical meeting are planned to prepare the document for final review. A Coordinated Research Project on the subject is planned to address long storage by assessing the safety of various types of existing storage facilities that are currently beyond operating beyond their design life. A Consultants Meeting is to take place in 2004.

The International Conference on Storage of Spent Fuel from Power Reactors (see Page 76) recommended that the IAEA provide assistance in the evaluation and research of the long term behaviour of fuel and storage components in order to realize the anticipated long storage periods and stressed the importance of international collaboration on specific issues. At the second meeting of the Technical Working Group on Nuclear Fuel Cycle Options and Spent Fuel Management held at Vienna in May 2003 [6.31], a recommendation was made that additional research and development is needed to obtain information on the long term performance of spent fuel and storage systems, including used materials.

Therefore, the IAEA is considering a continuation of the Spent Fuel Performance and Research Programme [6.32]. It is proposed to review the results from monitoring and research activities and to address the implications of fuel design changes on storage requirements.

6.4.3 Collection and Dissemination of Radwaste Storage Information by the IAEA

The IAEA's Net Enabled Waste Management Database (NEWMDB, see Subsection 11.1) is used to collect information about waste storage facilities in IAEA Member States. The intent is for the NEWMDB to be the most comprehensive source of information about waste storage facilities and stored waste inventories. As discussed in Subsection 6.3.2, the results of the first two data collection cycles with the NEWMDB were published on the Internet and on CD ROM. Reports are accessible on line or can be ordered from the NEWMDB web site [2.3]. The third data collection was held March to July 2004 and the results were published on the NEWMDB web site.

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7 RADIOACTIVE WASTE DISPOSAL

The purpose of this Section is to highlight some aspects of waste disposal that might be topical for some waste managers (e.g. closure or upgrading of near surface disposal facilities) or that have recently displayed some progress (such as the impact of innovative nuclear technologies on waste management). Additionally, the Section describes typical approaches to disposal and examples of activities carried out by some Member States (e.g. research and development for geological repositories).

The IAEA defines radioactive waste disposal as [4.12]:

Emplacement of waste in an appropriate facility without the intention of retrieval.

The key word in the definition is *intention* (please see Page 76). Even in the absence of an *intention* to retrieve, waste could be recovered from a repository as a last resort if the repository was mined. Mining waste could involve great costs and risks. In addition, even in the absence of an *intention* to retrieve, retrievability could be designed into a repository to facilitate waste retrieval should a future decision be made to retrieve it.

The following radioactive waste disposal related topics are discussed in the current issue of this Status and Trends report:

- emerging issues (Subsection 7.1),
- multinational/regional concepts for waste management facilities (Subsection 7.2),
- the impact of innovative nuclear technologies on radioactive waste management and decommissioning (Subsection 7.3),
- societal issues related to geological repositories (Subsection 7.4),
- research, development and demonstration in geological disposal (Subsection 7.5),
- example of the closure of a surface repository (Subsection 7.6),
- upgrading near surface disposal facilities (Subsection 7.7),
- the collection and dissemination of radioactive waste disposal information by the IAEA (Subsection 7.8).

7.1 Emerging Issues

Emplacement of waste in geological repositories aims to provide for its containment and isolation from the human environment for very long periods of time. Adequate long term safety can, therefore, be provided without reliance on active controls or for ongoing maintenance. Disposal at depth addresses safety concerns related to inadvertent or intentional human intrusion, which can be of significant concern for surface-based waste management facilities. Although continued institutional control should not be required for reasons of safety, the need to address IAEA safeguards requirements for fissionable material suggests a continuing need for some monitoring and possibly for other forms of institutional controls for security reasons. Addressing these latter requirements has been the focus of increasing attention in recent years [7.1] to [7.3].

In parallel with developments related to safeguards, progress has been made in the development of monitoring techniques, including methods that enable the conditions within the repository to be monitored remotely [7.4]. Such techniques offer the possibility of developing more comprehensive approaches to tracking the evolution of the repository system during construction, operation and after closure and, therefore, to confirm that the behaviour of the repository is within the expected bounds. At the same time, such techniques may allow for the long term surveillance of spent fuel and other materials subject to safeguards requirements to be addressed even after the repository has been closed.

Although the development of more sophisticated monitoring techniques may bring benefits both in relation to safeguarding the fissile material and in confirmation of repository performance, a clear distinction between these requirements should be maintained. As noted above, safety of a geological repository should not depend on any active system of institutional controls, as the continued existence of such controls cannot be guaranteed in the long term. On this basis, the only safety requirement for safeguards is that these should be implemented in such a way as not to unduly influence the long term safety of the repository.

Subsection 7.1.1 focuses on recent IAEA work to clarify the technical implications of safeguards requirements for geological disposal of radioactive waste, taking account of recent work in the Finnish and Swedish disposal programmes on this issue. Subsection 7.1.2 addresses recent advances in the development of monitoring strategies for geological repositories, particularly relating to the Yucca Mountain project (see Subsection 7.4.4.3 in the third issue of this Status and Trends report series [2.4]) and in European Union programmes.

7.1.1 Safeguards

The requirement for safeguards arises from the Treaty on the Non-Proliferation of Nuclear Weapons [7.5], which prescribes that Member States declare the quantities and location of source or special fissionable material (thorium, uranium or plutonium-bearing materials) in civil nuclear facilities. As such facilities include geological repositories, these are also subject to safeguards requirements and associated inspections would be conducted by the IAEA when these facilities are operational and contained accountable materials, with the aim of verifying the accuracy of declarations made by Member States.

It is likely that safeguards requirements will only be applied to specific wastes once these have been placed in a geological repository. These wastes are likely to include spent fuel from power and research reactors, unirradiated highly enriched uranium (HEU) and Plutonium (Pu) bearing waste (except when Pu is at very low concentrations) [7.6].

Although the IAEA has long experience in the implementation of safeguards in surface facilities, the application of this experience to geological facilities raises novel considerations, e.g. because of the lack of access to the fissile material once the repository is closed. Thus, further direct verification of the inventory of nuclear material is not possible and, should knowledge of the material content of the repository be lost, that knowledge cannot be restored. Retrievability (see the beginning of Section 7) offers the possibility to verify the waste in the future, since the waste would be accessible if retrieval is performed.

The IAEA's Programme for the Development of Safeguards Approaches for the Final Disposal of Spent Fuel in Geological Repositories [7.7], initiated in 1994, provided recommendations to the IAEA in 1998 on generic safeguards approaches for spent fuel conditioning facilities and for operating and closed geological repositories.

In the context of geological repositories, policies established by the IAEA include [7.8]:

- Safeguards requirements apply to spent fuel disposed in geological repositories for as long as the relevant agreement remains in force, i.e. including the post-closure period.
- The safeguards system has the following main components - verification of design information during design, construction and operation; verification of receipts and material flow; and maintenance of continuity of knowledge on nuclear material content.
- Safeguards requirements should be integrated into the repository design at an early stage in order to establish functional, non-intrusive and cost-effective safeguards.
- Design information should be provided to the IAEA at an early stage.

- The IAEA, in collaboration with the Member State, should establish all pertinent information about the original undisturbed site, preferably before excavation begins, in order to plan for safeguards measures.

In 1998, the IAEA established the Geological Repository Safeguards Experts Group [7.9] to provide advice on safeguards technology development for geological repositories and on implementing the generic safeguards approach at specific facilities. This Group has considered a range of topics including the use of geophysical techniques, baseline information and the interface between safeguards and radioactive waste management at different phases of the repository lifecycle.

Following a "decision-in-principle" by the Government of Finland in December 2000 to develop a geological repository at the site of the Olkiluoto power station (see Subsection 7.4.4.4 in the third issue of this Status and Trends report series [2.4]), the Radiation and Nuclear Safety Authority (STUK) approached the IAEA to determine what safeguards requirements will be required. In response to this request, the IAEA convened an expert meeting in April 2002 with the objective of identifying the information that should be collected by the IAEA during the pre-operational phase in order to have assurance of the integrity of the repository boundaries and of the spent fuel assemblies.

As a result of the meeting, it was agreed that Finland should provide, prior to the start of underground excavations at the site, a report comprising the best available initial baseline site data. Nuclear materials characterization was identified as an R&D priority, i.e. adequate information and knowledge about the properties of spent fuel items should be available before the fissile material is emplaced in the repository. The IAEA undertook to identify any changes needed to the type of data provided, leading, if necessary, to further site-specific R&D activities in geophysical, earth imaging and spent fuel characterization techniques.

The expert meeting identified various monitoring options that need site specific adaptation and further development:

- geophysical measurements - this includes: micro-seismic monitoring techniques that could detect, for example, underground activities such as drilling and tunnelling; ground penetrating radar data collected during construction may be used to show the potential for the detection of undeclared voids;
- satellite and aerial surveillance methods - used to detect any activities that could lead to the diversion of materials from the disposal facility;
- radiological monitoring - any attempt at reprocessing within the repository will release both particulate and volatile radionuclides;
- hydrogeological monitoring (temperature, groundwater chemistry, groundwater pressure, solute chemistry and mineralogy) - enables the response of the surrounding host rock to be tracked; and
- accumulation of environmental data (e.g. meteorology, hydrology, local ecology) - to assess the suitability of the land above a repository for alternative land uses.

It is evident that methodologies exist that may guarantee maintaining safeguards within the post-closure phase of a geological repository. However, their implementation needs a detailed elaboration of both the administrative and the practical procedures, which has become a topical issue in some countries with impending applications for the construction of geological repositories.

Currently, the IAEA is preparing a technical document on the "Technological implications of Safeguards Requirements for the Disposal of Radioactive Waste in Geological Repositories" (at time of writing, the latest draft was dated April 2004) [7.6].

7.1.2 Long Term Monitoring

Monitoring is considered, for various reasons, as a necessary component of developing, operating and closure of a repository. A draft IAEA Safety Standard [7.10] states that "*A programme of monitoring shall be defined and carried out prior to and during the construction and operation of a geological disposal facility*". Monitoring is defined as "*.. continuous or periodic observations and measurements of engineering, environmental or radiological parameters, to help evaluate the behaviour of components of the repository system, or the impact of the repository and its operation on the environment*" [7.11]. The primary objective for monitoring is to obtain information that will help in making decisions on the implementation of successive phases of the disposal concept [7.12].

Some IAEA Member States consider that monitoring of near surface disposal facilities is required up to any decision releasing the site for unrestricted use, which can be on the order of 300 years after facility closure (active and/or passive institutional control phase(s)). However for geological disposal, a widely accepted view is that once the wastes are isolated in a sealed repository, the long term safety should not require any further actions of future generations since the waste is isolated in a deep geological formation. This is in keeping with the "inter-generational equity principle" [7.13]. This could be interpreted as no necessity for post closure monitoring activities, however they may be performed, if desired by future generations [7.14].

The main purposes for monitoring can be, in general terms [7.15]:

- ***information***, to collect inputs for making management decision in all stages of a repository lifecycle, and to strengthen confidence of the society in an ability of assuring the safe performance of the disposal facility,
- ***observation***, to assure that data are gained which are needed for understanding of system behaviour and predicting the main phenomena occurring in the system,
- ***control***, to survey the functioning of a facility through the parameters representing adequately its evolution,
- ***protection***, to receive early warning on a start of unacceptable processes that may result in non-safe status of a facility and to initiate remediation activities for mitigating their consequences.

Monitoring of a geological disposal system during its phased implementation process is based on the following generally accepted principles [7.12]:

- both conventional and radiological safety of a disposal facility shall be observed,
- long term safety shall not rely on post-closure monitoring,
- long term safety shall be assured by the design of a disposal system (a convincing safety case shall be developed prior to waste emplacement),
- monitoring activities shall not compromise long term safety of a facility (no significant disturbance to the disposal system shall be proven), and
- a societal role of monitoring shall be considered, which may call for continuation of monitoring for as long as required by future generations.

Monitoring should be carried out during the whole lifecycle of a repository. In fact, it should start prior to any on-site technical activities to establish baseline information. This information is important for characterization of the undisturbed environment of a proposed disposal system. These characteristics are used in all other stages for comparative evaluation of the evolution of the disposal system. The stages for siting a geological facility are defined in reference [7.16], but for consideration of monitoring objectives, the following seven stages can be defined:

- surface exploration,

- access construction and underground exploration,
- construction of the repository,
- placement of waste and near field engineered barriers,
- disposal tunnel/vault backfilling,
- backfilling of remaining openings and repository sealing, and
- post closure.

Monitoring is a way of gaining information and is carried out by a variety of methods [7.11] – see the Yucca Mountain Project description in Subsection 7.4.4.3 in the third issue of this Status and Trends report series [2.4] and Reference [7.17] for examples. Naturally, it is envisaged that quality assurance and quality control principles are fully employed in planning, performing and recording all monitoring activities. Databases of monitoring results should be properly managed and safely stored on appropriate media resistant to aging [7.18], [6.3]. The following are consider to be prime uses of monitoring information:

- supporting management decisions in a staged programme of repository development, which may include, for example, determination of optimum time to backfill and seal in the context of long term stability;
- strengthening understanding of system behaviour, such as the hydraulic and mechanical evolution of the system in the pre-closure period;
- societal decision making, typically, establishing baseline information for the sites in consideration for latter demonstration of a safe operation of the facility;
- accumulating an environmental database, to provide the future generations as much data as possible, even if not required for current decisions, for any later re-consideration of the uses of repository land and host rock;
- nuclear safeguards, in all cases when repository accepts fissile materials - this type of monitoring may be performed even in post-closure phases; and
- making decisions based on monitoring information, which requires thorough demonstration and understanding of the implications of the monitoring results and an appropriate level of responses in the earliest stages of monitoring programme.

Broadly speaking, there is a clear need for monitoring activities, which may vary for different stages of a repository lifecycle and that may address different needs and uses. Techniques and procedures are available for all types of surface and underground data acquisition that can currently be envisaged.

7.2 Topical Issue: Multinational/Regional Concepts for Waste Management Facilities

Note: Due to unforeseen circumstances, the publication of this Status and Trends report was delayed for several months after the "final draft" was written. During the delay period, the document "Developing Multinational Radioactive Waste Repositories: Infrastructural Framework and Scenarios of Cooperation", IAEA TECDOC Series No. 1413, was published (October 2004). It can be downloaded free of charge from the IAEA via the following link:

http://www-pub.iaea.org/MTCD/publications/PDF/te_1413_web.pdf

Multinational cooperation on key aspects of the nuclear cycle is required by some Member States and it is actively promoted by the IAEA [7.1] to [7.3], [7.19]. Multinational cooperation is not limited to disposal facilities, some Member States have expressed a clear interest in regional storage initiatives by some Member States with smaller nuclear programmes [7.20]. An IAEA technical document is in preparation regarding the Regional Spent Fuel Storage Facility concept (RSFSF). Among the document's draft conclusions, the following summarizes a potential for its implementation:

> *It appears from the preceding discussions that the RSFSF concept is technically feasible and potentially economically viable. The group did not identify any obvious institutional deficiencies that would prevent completion of such a project. Storing spent fuel in a few safe, reliable, secure facilities will enhance safeguards, physical protection and non-proliferation benefits. The committee also recognized that the political, social, and public acceptance issues are real and difficult to address. The added difficulty due to the regional nature of the facility could well be balanced by the benefits. However, the State considering hosting such a site and the States considering being customers for such a site will need to make their own decisions on the relative weights to place on these risks and benefits and the final decision on the establishment of a RSFSF.*

In response to requests from several Member States expressing an interest in multinational disposal options, the IAEA published a technical document in 1998 outlining the important factors to be considered for realizing such options [7.21]. The IAEA reviewed this previous study, taking into account developments since its publication in 1998 as well as current activities in the field of multinational repositories. This resulted in new draft document that includes a more specific examination of possible implementation scenarios and a more detailed specification of implementation conditions [7.22], [7.23]. The three main scenarios identified in the draft document are discussed below; they are classified according to the degree of self-sufficiency and independence of the repository host country:

Type I: Add-on scenario. The host country offers to complement its national inventory of wastes for disposal by wastes imported from other countries.

> This scenario is characterized by the availability of all necessary resources and capabilities in the hosting country. It requires that the hosting country have the political will, the technical and financial resources and the natural conditions (geology) to develop a repository. In practice, in this add-on scenario, the repository remains effectively a national repository, but with a part of the waste inventory coming from abroad.

Type II: Cooperation scenario, in the case where multinational cooperation is, by necessity or choice, an indispensable element of repository development and implementation.

> This is characterized by the participation of (partner) countries in developing a repository programme jointly together with the potential hosting country. In this case, one or more other countries interested to dispose their waste in the potential hosting country or countries will be involved directly in repository development and implementation. There are various sub-scenarios that can be included in this category; such as:
>
> > *Type II-a: Several industrialized countries with relatively small nuclear energy programmes decide to cooperate for the disposal of their radioactive waste in a host country satisfying all necessary technical requirements*
> >
> > *Type II-b: Countries with small quantities of radioactive wastes and in varying stages of development seek assistance from each other and cooperate to ensure that one of them acquires all necessary technology and institutional structures*
> >
> > *Type II-c: Specializing of repositories for specific types of waste, possibly combined with arrangements for international exchanges.*

Type III: International scenario, in which a higher level of control and supervision is implemented.

> It has been suggested that global acceptance of a multinational repository might be enhanced if the operation were fully in the hands of an international body. The host country would, in this scenario, effectively cede control of the necessary siting area to the international body. This scenario seems unlikely in the foreseeable future because such transfer of sovereignty is of extreme political sensitivity.

The above-mentioned scenarios should be considered as representative only. The scenarios that will be considered more fully in the future will depend on the needs and interests of potential hosting countries and on the capabilities of partner countries to respond to their requirements for implementation. Due to the very limited experience to date, it is difficult to predict the scenarios that are the most promising.

The issues and factors that need to be considered for multinational cooperation include, but are not limited to:

- the ethics of disposal (e.g., burdens for future generations),
- non proliferation (see Subsection 7.1.1),
- safety and security,
- economics and financial arrangements,
- technical requirements,
- treaties and legal agreements,
- regulatory issues,
- socio-political issues, and
- the role of international institutions.

The contributors that worked on the various drafts of the cited draft document share the conclusions of the document published in 1998 and have come to following additional conclusions:

- Multinational repositories can enhance global safety and security by making timely disposal options available to a wider range of countries. For some Member States, multinational repositories are a necessity, if safe and secure final disposal of long lived radioactive waste is to replace indefinite storage in surface facilities.
- The global advantages of multinational repositories are clear and the benefits can be significant for all parties, if they are equitably shared. For individual countries, the balance of benefits and drawbacks resulting from participation as a host or as a partner must be weighed by the appropriate national decision making bodies.
- Implementation of multinational repositories will be a challenging task. However, there are a number of conceivable scenarios under which their development might take place.

The contributors made the following recommendations:

- The concept of multinational repositories should continue to receive support from all countries that have an interest in a shared disposal solution.
- Discussion on the advantages, drawbacks and boundary conditions for multinational concepts can be initiated by interested countries without prior definition of potential host countries.
- Proponents of national and multinational repository concepts should acknowledge that both types will be implemented and should try to ensure that activities undertaken in either case do not negatively impact the other.

An immediate practical step could be to facilitate multinational or regional disposal concepts for spent/disused sealed radioactive sources.

7.3 Topical Issue: Impact of Innovative Nuclear Technologies on Radioactive Waste Management and Decommissioning

The production of commercially available nuclear energy has been mainly based on power reactors using fuel enriched in U-235 (typically the fuel has 95-97% U-238 and 3-5% U-235, natural uranium has 0.72% U-235 by mass). This required the development and implementation of uranium enrichment facilities [7.24]. It was recognized that the energy potential of uranium resources could be increased using "nuclear breeding" where uranium and thorium resources offered an essentially inexhaustible fuel resource. Breeder reactors can produce Pu-239 from U-238 and fast breeders can produce more fissionable fuel than they consume [7.25]. Subsequently, Pu-U and Pu-Th fuels would be used to generate electricity.

These considerations lead to a two stage strategy for future nuclear generation:

- The use of thermal once-through reactors to generate energy and to accumulate plutonium for the start-up of advanced fuel cycles and breeder reactors, being developed concurrently, e.g., breeders; and
- The deployment of breeder reactors and advanced fuel cycles to support large-scale growth of nuclear power to replace, over time, traditional fossil energy sources.

The issue of sustainable development is addressed in programmes aimed at developing advanced nuclear power reactors and deploying new fuel cycle systems. Among them, the most significant are the IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO, see Subsection 7.3.1) [7.26] and the US initiated Generation IV International Forum (GIF, see Subsection 7.3.2) [7.27]. The future evolution of nuclear power will impact on the quality and quantity of radioactive waste that is generated.

INPRO is based on an IAEA General Conference Resolution in September 2000 and additional resolutions in 2001 and 2002. Additional endorsement came in the UN General Assembly resolutions on the IAEA (A/RES/56/94, 2001 and A/RES/57/9, 2002) that emphasized "*the unique role that the Agency can play in developing user requirements and in addressing safeguards, safety and environmental questions for innovative reactors and their fuel cycles*" and stressed "*the need for international collaboration in the development of innovative nuclear technology*". The Terms of Reference for INPRO were established in November 2000 and progress to date is described in reference [7.28].

The generation of radioactive waste from innovative nuclear reactor technologies is also followed within projects supported by the European Commission within the 5th and 6th framework plans for research and technological development. In 2003, a Thematic Call in the area of "Euratom Research and Training programme on Nuclear Energy" was announced. The call includes an objective to "*determine practical ways of reducing the amount and/or hazard of the waste to be disposed of by partitioning and transmutation and to explore the potential of concepts for nuclear energy to produce less waste*" within its scope [7.29]. The purpose of the objective is to assess the benefits and disadvantages of partitioning and transmutation on the fuel cycle as a whole and, in particular, for waste management and geological disposal. The scope of the project mainly includes system studies to evaluate the health, environmental, social and economic benefits (or disadvantages) of partitioning and transmutation applied on an industrial scale to the fuel cycle and establishing performance criteria for the different steps. Within this, all operations and waste streams in the fuel cycle that would be significantly affected by partitioning and transmutation will be addressed.

The U.S. Department of Energy (DOE) prepared a report on advanced fuel initiatives to respond to Congressional direction [7.30]. Congress instructed the DOE to provide answers to several questions related to the spent fuel separations and transmutation research activities. Specifically, Congress directed the DOE to:

- compare chemical and pyroprocessing, accelerator-driven transmutation, and fast reactor transmutation alternatives, including full disclosure of all waste streams;
- estimate the life cycle costs to construct, operate, and decommission and decontaminate all necessary facilities;
- compare the proliferation resistance of the various technologies;
- provide a strategy for siting new processing and disposal facilities that would be required for the various reprocessing and transmutation alternatives;
- use the once-through fuel cycle as presently used in the USA and the amount of spent nuclear fuel presently scheduled for disposal in the geologic repository as the baseline for all comparisons; and
- present the DOE's strategy for siting the new processing and disposal facilities that would be required for various processing and transmutation alternatives, assuming a capacity sufficient to process the amount of spent fuel presently scheduled for geologic repository.

The information presented in the report reflects the current state of R&D knowledge on separation and transmutation technologies. Regarding disposal, the report states that these questions cannot be answered until the technologies to be employed have been selected and necessary environmental impacts studied. However, the DOE anticipates that any advanced fuel cycle facilities built in the USA would be constructed and operated by the private sector with appropriate incentives that reflect the national benefits of implementing technology approaches to managing nuclear waste.

7.3.1 INPRO

Regarding waste management, INPRO adopts the nine principles as defined the IAEA Safety Fundamentals "The Principles of Radioactive Waste Management [6.2]. From these principles, INPRO defined six user requirements, associated criteria (expressed in the form of 20 indicators and relevant acceptance limits). At this stage of the INPRO, the user requirements are only qualitative. The requirements are:

Predisposal waste management: Intermediate steps between generation of the waste and the end state should be taken as early as reasonably practicable. The design of the steps should ensure that all important technical issues (e.g., heat removal, criticality control, confinement of radioactive material) are addressed. The processes should not inhibit or complicate the achievement of the end state.

End state: For each waste in the energy system, a permanently safe, achievable end state should be defined. The planned energy system should be such that the waste is brought to this end state as soon as reasonably practicable. The end state should be such that, on the basis of credible conservative analysis or demonstrated operation, any release of hazardous materials to the environment will be below that which is acceptable today.

Adverse effects on human health: Waste management systems should be designed to assure that their associated adverse radiological and non-radiological effects on humans are below the levels acceptable today. Because the waste management systems are integral parts of the overall energy system, their designs should be optimized with respect to adverse effects as part of the optimization of the overall energy system.

Adverse effects on the environment: Waste management strategies should be such that the adverse environmental effects from all parts of the energy system and the complete life cycle of facilities are optimized. The cumulative effects over time and space, without regard to national boundaries, should be considered.

Reduction of waste at the source: The energy system should be designed to minimize the generation of wastes and particularly wastes containing long lived toxic components that would be mobile in a repository environment.

Attribution of waste management costs: The costs of managing all wastes in the life cycle should be included in the estimated cost of energy from the energy system, in such a way as to cover the accumulated liability at any stage of the life cycle.

The INPRO report [7.28] also recommends areas for research, development and demonstration (RD&D) that offer particularly good potential for reducing adverse effects due to the presence of long lived radionuclides and indicates objectives and a time requirements for each of them. These RD&D areas are:

- methods for characterizing wastes in the nuclear fuel cycle to reduce occupational exposure, improve efficiency and facilitate showing compliance with waste acceptance;
- waste treatment methods to reduce radiological impact from storage and disposal of waste and to decrease the amount of hazardous material requiring disposal;
- reprocessing of spent fuel to improve waste stream characteristics and to reduce secondary wastes;
- methods to increase the safety of storage;
- partitioning and transmutation to reduce long lived radioactive components in HLW and to enhance the efficiency of partitioning operations;
- geological disposal to demonstrate disposal technologies, to improve geological characterization, to enhance understanding of hydrogeochemical transport processes, to improve long term monitoring technologies and to facilitate the detailed design of geological repositories;
- long term human factor analysis to assess risks associated with waste management systems that require long term institutional controls; and
- design-based comparison of waste arising from proposed advanced reactors and fuel cycles to incorporate safety of waste management and fuel reprocessing in the fuel cycle evaluations.

7.3.2 Generation IV International Forum (GIF)

To advance nuclear energy to meet future energy needs, ten countries - Argentina, Brazil, Canada, France, Japan, the Republic of Korea, the Republic of South Africa, Switzerland, the United Kingdom, and the United States of America - have agreed on a framework for international cooperation in research for a future generation of nuclear energy systems, known as Generation IV [7.31]. The ten countries have joined together to develop next generation nuclear energy systems that can be licensed, constructed, and operated in a manner that will provide competitively priced and reliable energy products while satisfactorily addressing nuclear safety, waste, proliferation, and public perception concerns. The objective for Generation IV nuclear energy systems is to have them available for international deployment about the year 2030, when many of the world's currently operating nuclear power plants will be at or near the end of their operating licenses.

Beginning in 2000, the countries constituting the GIF began meeting to discuss the research necessary to support next-generation reactors. From those initial meetings a technology roadmap to guide the Generation IV effort was begun [7.32]. The organization and execution of the roadmap became the responsibility of a Roadmap Integration Team that is advised by the Subcommittee on Generation IV Technology Planning of the U.S. Department of Energy's Nuclear Energy Research Advisory Committee. The roadmap and other planning documents will be the foundation for a set of R&D program plans encompassing the objectives of deploying more mature nuclear energy systems by

2010, developing separations and transmutation technology for reducing existing stores of spent nuclear fuel, and developing next generation nuclear energy systems in the long term.

As preparations for the Generation IV Technology Roadmap began, eight goals for Generation IV were defined in the four broad areas of sustainability, economics, safety and reliability, and proliferation resistance and physical protection. The goals that are most relevant to waste management are:

> Sustainability–1. Generation IV nuclear energy systems will provide sustainable energy generation that meets clean air objectives and promotes long term availability of systems and effective fuel utilization for worldwide energy production.
>
> Sustainability–2 Generation IV nuclear energy systems will minimize and manage their nuclear waste and notably reduce the long term stewardship burden, thereby improving protection for the public health and the environment.

The activities of GIF consist of planning activities and, therefore, there are no immediate direct impacts on waste management issues.

7.4 Topical Issue: Societal Issues Related to Geological Repositories

There is now a widely held view that one of the greatest challenges to the development of geological repositories for HLW or spent nuclear fuel is the need to develop greater public confidence is this waste management approach. The scientific and engineering aspects of waste management safety are therefore no longer of exclusive importance, with issues relating to the quality of the decision making process being of comparable importance to a constructive outcome [7.33].

During the past decade many of those countries with significant amounts of radioactive waste have begun to modify their decision-making procedures with the aim of introducing more deliberative and inclusive decision making processes – see Reference [7.34] for one example. In some countries, decisions about future waste management strategies and/or the selection of potential disposal sites are being considered through parliamentary procedures. In others, wide public participation processes, including the participation of non-governmental organizations, are being organized to assist with the determination of future waste management strategies. There are also many instances of local participatory processes relating to local waste management issues having been established or strengthened, leading to broader public support for the eventual outcomes.

It is now widely believed that an important element in establishing public confidence in a particular waste management strategy is the perceived trust and credibility of the implementing organization and of the regulatory authority. Establishing trust can be enhanced when an inclusive approach to public involvement is adopted from the beginning of the planning process to help ensure that all those who wish to take part in the process have an opportunity to express their views and have access to information on how public comments have been considered and addressed. Experience suggests that trust is promoted by providing access to accurate and understandable information about the development programme, conceptual design and the siting process at different levels of detail suitable for a broad range of interested parties. The openness and traceability of the decision making process is important. In addition to the perceived trust and credibility of the responsible organization, other aspects of public acceptability can be location-specific, based on local requirements and cultural context [7.35].

Any attempt to involve the public in an effective way should adhere to the following principles [7.36]:

Participation should be:

- started early and occur throughout the process (with defined cycles of activity),
- interactive - a two-way process including feedback, and
- inclusive, transparent and honest.

A key requirement is the development, at the outset of a disposal programme, of a public involvement programme that defines the overall objectives and outlines a series of public activities connected with the various phases of the assessment process. The public involvement programme needs to provide easy access by any interested individuals and must be fair, i.e. the public must be able to contribute to defining the scope and nature of the programme itself.

The audiences for public involvement activities may include representatives from local communities, administrative units (e.g. national, regional and local), government officials, indigenous peoples where appropriate, regulatory agencies, community and public interest groups, environmental organizations, industry and trade groups, the scientific community and the news media. Different audiences may be involved through the various phases of the repository life cycle and be drawn from the local, regional or national levels, as appropriate. For example, during the development of national policy, the relevant audience may be the entire general public within a Member State.

As the process moves forward into more focused siting activities, the issues may become more narrowly defined, as alternatives are considered and a specific site is proposed. At this time, interest may be focused on the communities located nearest to the proposed site as well as communities bordering that location and those along likely transport routes. Significant levels of interest may exist at regional and national levels throughout the project development phase. Interest will also extend to neighbouring countries, as mandated under a number of international treaties and conventions, particularly if the proposed facility is located near an international border.

In some IAEA Member States, committees representing a range of local community interests (e.g. local government, schools, business and environmental groups, and interested citizens) have been formed to assist impact assessment and impact management planning activities. In addition, experience suggests that these local committees may have continuing value during the repository construction and operation phases to help with the implementation of the impact management measures. They also can monitor related repository operations and serve as an independent information source to interested parties.

7.5 Topical Issue: RD&D in Geological Disposal (Canada, Czech Republic, Finland and Japan)

At the recent international conference on geological repositories, held in Stockholm, Sweden in December 2003 (see References [7.1] and [7.37] and Subsection 12.1.4), it was noted that the knowledge and understanding of major processes and phenomena associated with the disposal of radioactive waste in deep geological formations have made significant progress partly thanks to *in situ* observations and testing performed in underground research laboratories. The importance of international cooperation on R&D issues and its contribution to developing and consolidating the scientific and technical basis on geological disposal was discussed. These joint activities, which are often performed as multinational cooperation projects, complement national efforts.

The scope of R&D activities varies significantly in different countries according to the extent of the national geological repository programme, general strategy of its implementation and timing, public awareness, available technical and scientific capabilities, financial sources, and other aspects. To illustrate these differences in performing research activities, the following four examples were selected representing diverse approaches and different levels of the status of a repository development:

- Canada, preparing a national strategy for spent fuel management and, therefore, has frozen generic research previously conducted in an underground laboratory,
- Czech Republic, planning to commission a geological repository within 60 years and performing only selected R&D activities,
- Finland, progressing to the construction of a repository after a site was selected and confirmed by the national authorities, and

- Japan, opening a large, systematic programme aimed at development of a geological repository clearly addressing the defined needs of the country.

CANADA (large nuclear power programme, most R&D on hold, no planned date for a repository)

In Canada, there are 22 power and 16 research reactors that will generate nearly 3.6 million fuel bundles with approximately 70 000 tU (tonnes Uranium). In 1978, the Canadian Nuclear Fuel Waste Management Programme was announced with the intention of verifying the safety and feasibility of disposal in igneous rocks. Atomic Energy of Canada Limited (AECL) was given role of developing the technology for conditioning and disposal. In 1981, it was announced by the Government of Canada and the Province of Ontario that no disposal site would be selected until after the concept had been approved.

Following an Environmental Impact Statement issued by AECL in 1994, an Environmental Assessment Panel was created to make recommendations to the Federal Government on the safety and acceptability of the disposal concept. In 1998, the Panel found the safety of the AECL concept technically sound, but public policy issues were not well addressed.

In response to the Panel's recommendations, the Nuclear Fuel Waste Act was passed by the Federal Government in November 2002. The Act required the utilities to establish a segregated fund for nuclear waste management and it established the Nuclear Waste Management Organization (NWMO, [7.38]). The NWMO was directed to complete a study of options for the long term management of nuclear fuel waste and to recommend a preferred option (geological disposal, long term storage at reactor site or in a central facility). Various discussion documents will be issued to gather opinions on the way forward for Canada; namely "Asking the right questions?" (issued in November 2003); "Understanding the choices" (mid 2004); "Choosing a way forward" (draft early 2005, final study by November 2005).

In 1982, AECL started construction of the Underground Research Laboratory (URL) near Lac du Bonnet, in the Province of Manitoba. The objective for the URL was to carry out both site evaluation (characterization of the rock, groundwater flow and hydrogeochemistry) and underground experimentation (studies of geological barrier and the engineered components of the repository sealing) [7.39]. Completed in 1989 and located at AECL's Whiteshell Laboratories, the URL became the centre of Canadian research, development and demonstration on geological disposal. The specific areas of studies at the URL are formulated along three broad study areas [7.40]:

- site characterization, or long term geologic monitoring methodologies,
- solute transport through fractured and non-fractured crystalline rock,
- support of the engineered design of repository sealing system.

The laboratory is situated in a granite batholith towards the western edge of the Precambrian Canadian Shield. This geological formation has surface area of some 1 400 km^2 and extends in depth between 6 and 25 km, The rock is approximately 2.6 billion years old. The URL has two experimental levels (240 m and 420 m) with 1.6 km of horizontal excavations and two additional drilling stations at 130 m and 300 m. The total excavated volume is 32 270 m^3.

The R&D programme was initiated in 1990 and consisted of seven major operating phase experiments and two experimental programmes. Over the years, this expanded to 33 experiments and experimental programmes; see Table 7-1.

The URL R&D programme was carried out in several phases: siting, site evaluation, construction, and operation phases have been completed while the closure phase is under consideration. Each phase involved various R&D activities, either in direct experimental work or in developing relevant methodologies. Most of the experiments in Table 7-1 have been completed but some are still underway and are to be completed in 2004 prior to the anticipated initiation of URL closure activities. In order to make the most of the anticipated closure of the URL, a Repository Closure and Post-closure Project (RECAP) has been proposed to the international community. RECAP would demonstrate and evaluate activities to be carried out in the final phase of a repository lifetime. It is also is intended to include extended post-closure monitoring of engineered seals and the local hydrogeologic conditions. In early 2004, a decommissioning plan for the URL had been drafted and was under consideration by AECL management. Without initiation of RECAP activities or a change in the fiscal conditions associated with the URL, it is anticipated that decommissioning will be initiated in the summer of 2004 with no decommissioning-related studies or monitoring occurring.

Table 7-1: Overview of Experiments Performed in URL

Solute transport	In highly fractured rock (HFR)	URL characterization programme	Multi-disciplinary
	In moderately fractured rock (MFR)	Tunnel sealing experiment (TSX)	
	Quarried block radionuclide migration experiment (QBRME)	Composite seal experiment (CSE)	
	In-situ diffusion experiment	Engineering design of repository sealing system (ENDRES)	
	EDZ solute transport test		
	Recharge infiltration experiment (RIEX)	ANDRA engineered blast feasibility study	Excavation damage/excavation stability
	URL hydrogeological monitoring		
	JAERI rock mass experiment	Mine-by excavation response test	
Materials and sealing studies	Buffer/container experiment (BCE)	Heated failure test (HFT)	
	Isothermal buffer-rock-concrete plug interaction test (ITT)	In situ stress measurement programme and stress characterization in deep boreholes and fractured rock	
	Fracture zone grouting experiment		
	High pressure grouting simulator	Blast damage assessment study (BDA)	
	Large concrete blocks	Mine-by connected permeability test	
	Light backfill placement trials	Excavation stability study (BDA)	
	Seal and interface evaluation/effect of salinity (SEAS)	Thermal-hydraulic experiment (THE)	
	Buffer-coupon long term test (BCTLT)	Thermal-mechanical stability study (TMSS)	
	Microbial borehole a microbial studies		
	Concrete-rock interface studies (CRIS)	Room 209 excavation response test	

A significant part of R&D activities is the dissemination of knowledge gained from experiments. In the case of URL, this was performed not only at the national level through the promotion of student and doctorate studies, but also internationally. The URL was among founding members of the IAEA's Network of Excellence on Training and Demonstrations in Underground Research Facilities on the Geological Disposal of Radioactive Wastes [7.41]. Within this framework, a training course took part in the URL in the summer of 2003. Further training of IAEA-sponsored Fellows occurred in February –March 2004 with 3 Fellows being hosted at the URL and participating in the decommissioning of the Tunnel Sealing Experiment.

CZECH REPUBLIC (small nuclear power programme, long-term perspective on radioactive waste management)

The Czech power utility [7.42], ČEZ, operates six NPP with installed capacity of 3 760 MWe. The share of nuclear energy within ČEZ was 42.5% in 2003, which corresponded to approximately one third of the country's total electricity production. A total of 3 700 tU from spent fuel are expected to be generated over 40 years of NPP operation. The management of spent fuel declared to be waste is the responsibility of the Radioactive Waste Repository Authority (RAWRA).

In compliance with the national energy policy, systematic studies for development of a geological repository in the Czech Republic commenced in 1992 when a state supported project was launched aimed at conceptual activities. The project was managed by the Nuclear Research Institute (NRI) and supervised by a "Council of 6" consisting of spent fuel producers, governmental bodies and regulators. The project was completed in November 1999 [7.43]. During this period, RAWRA was created (based on the Atomic Law approved in 1997) and since 1998 it has been responsible for running the programme and also for co-ordinating all relevant R&D activities.

The current approach of the Czech Republic towards the final step of the nuclear fuel cycle is formulated in the national "Concept of Radioactive Waste and Spent Nuclear Fuel Management", approved by the Czech Government in May 2002 [7.44]. This crucial document proposed the State's long term strategy and mandates the following:

- ensure the storage of high level waste and spent fuel by generators until a geological repository becomes operational,
- until 2015, include two sites suitable for repository construction into the territorial plan,
- until 2025, demonstrate feasibility of repository construction in one of the two,
- after 2030, start construction of an underground laboratory at the selected site, and
- support research and development of alternative processes for spent fuel management.

The main assumption governing the programme is based upon a statement by the main spent fuel producer, ČEZ.

Shipment of spent fuel to a repository is expected to commence in 2065. Until that time, spent fuel would be stored in transport-storage containers.

According to the Atomic Law, RAWRA is, among others, responsible for a coordination of the research and development for the disposal of radioactive waste and spent nuclear fuel. There are two main directions - R&D aimed at development of a geological repository and generic research for the management of HLW and spent fuel in a broader sense. While the former deals mostly with applied science and targeted research, the latter is a typical example of basic research and includes, exclusively, partitioning and transmutation studies.

The geological repository development programme completed a conceptual planning stage in 2002. As a result, six study sites (all in granitic formations) were selected for continuation of technical activities. All six have been recently studied, such as site screening and characterization, design optimization studies, safety considerations and experiments aimed at characterization of engineered barrier system materials [7.45].

Geological investigations in this initial stage are classified by Czech legislation as "Research of the Homogeneity of the Czech Massif". To date, airborne geophysical investigations of selected regions have been performed, which should be followed by surface geophysical investigations, and geological and hydrological mapping. At the same time, the "Testing Site Project" is being carried out, which aims at providing a training matrix for mastering some geological techniques and methodologies for their interpretation. However, the way in which these testing matrices are being selected and characterized can be considered as the development and testing of the methodologies to be applied at study sites.

Design studies are currently underway as a follow up to the generic designs of a geological repository. Their goal is to specify and optimize technical solutions proposed, conservatively and/or alternatively, in the original conceptual design document. Preference is given to problems with direct impact on specification of siting requirements, such as disposition concept, size of surface facilities, layout of the underground facilities, transportation of packed fuel underground, etc.

General knowledge about potential materials for construction of engineered barriers is extensive. Even if only verification of their use in hydrogeochemical conditions of the considered host rock is needed within the Czech programme, some research has been initiated on collecting real data for safety and performance assessment studies. The work is aimed at the selection of sealing/buffering materials from domestic deposits (bentonites, montmorilonitic clays). It will also look at suitable materials for the packages and overpacks for spent fuel and their degradation, as well as for packaging of ILW (Czech classification, see Section 3) to be disposed of in the geological repository.

To support safety case development, studies have been carried out on both natural and anthropogenic analogues. With natural analogues, migration and chemical speciation of U mineralizations among clayey layers is investigated. Dissolution/migration rates and sorption characteristics of anthropogenic analogues are being studied at dumping sites where U coloured glass and U contaminated slag from production of non-ferrous metals have been kept for several centuries. Also, sorption and diffusion of radionuclides in concrete samples that were in contact for long times with water contaminated by products of natural decay chains (e.g. Ra) have been tested.

Partitioning and transmutation studies are being carried out in the following three directions: pyrochemical reprocessing of spent U and Th fuel, hydrometallurgical partitioning, and physical studies of molten salt reactor (MSR) for Pu incineration. All experiments are incorporated in EC supported international projects.

A significant part of the research has relied on and has been performed in co-operation with foreign partners. Joint actions have been based on bilateral contracts (ENRESA (Spain), GRS (Germany), NAGRA (Switzerland), POSIVA (Finland), and SKB (Sweden)) or have been a part of international projects supported by the European Community within the 5th and 6th Framework Programmes (such as FEBEX, SPIN, BIOCLIM, PADAMOT, NF-PRO, RED-IMPACT, PYROREP, EUROPART, MOST). Czech institutions have also been involved in projects of the Nuclear Energy Agency of the Organization of Economic Cooperation and Development (OECD/NEA) (Thermochemical Database project, Sorption project) and in Co-ordinated Research Programmes of the IAEA.

FINLAND (small nuclear programme, advanced stage of repository development)

Finland has 4 NPP with an installed capacity of 2 656 MWe providing more than 30% of national electricity consumption. The total amount of spent fuel to be disposed (estimated for 40 years of NPP operation) is some 2 600 tU (330 tU were shipped previously shipped to the former Soviet Union for reprocessing). The total amount of fuel may change since extension of reactor lifetime and an increase of national nuclear capacity are under discussion [7.46]. The national strategy of spent fuel management prefers direct disposal of spent fuel in a depth of some 500 m in a granitic formation, requires the site be on national territory and indicates the repository shall be operational in 2020.

Finland has no institutes dedicated solely to nuclear research. Therefore, R&D on the management and disposal of wastes is co-ordinated by POSIVA (the national waste management agency) and performed by the companies operating NPP, namely TVO and FORTUM. Starting from 2003, the R&D will be evaluated and outlined in 3 years intervals [7.47]. In addition, the Radiation and Nuclear Safety Authority (STUK) carries out internal research or finances research in universities and research institutes. To make publicly funded nuclear energy research result-oriented and efficient and to facilitate international cooperation, since 1989 most of the research has been organized as national programmes. Currently, the third generation of programmes, the "Finnish Research Programme on Nuclear Waste Management" (KYT 2002-2005), is under way [7.48].

The disposal concept was selected in the late 1970s - it is based on the Swedish KBS-3 method [7.49], even though some variations have been recently considered (like horizontal tunnel emplacement). Repository siting was initiated in late 1980s and through site characterization, detailed investigations including drilling campaigns, safety evaluations, and Environmental Impact Assessment studies, a final recommendation was issued in 1999 [7.50]. The Finnish Parliament ratified the decision on 18 May 2001.

Reflecting the political decision, POSIVA should apply for construction license by 2012. In between, technological procedures and facilities shall be developed and designed as well as site characterization completed and the preliminary results confirmed. Also, identification of particular rock massifs suitable for hosting the facility is needed. All this information will be interpreted in the form of a safety case that is required to support the construction application. The particular programme activities will be staged according to the progress of construction of the underground rock characterization facility, ONKALO, which should be completed by 2010.

The overall objective and a basic structure of R&D in the pre-construction phase are outlined in Reference [7.46] while particular activities to be carried out in 2004 - 2006 are developed in detail in Reference [7.47]. A generic feature of these plans is that all activities are focusing on technical outputs directly involved in the demonstrating feasibility and safety of the proposed disposal system. These activities reflect the legislative needs on principal documentation to be prepared for the construction license application. The documentation consists of:

- detailed technical design of the facility (both surface/subsurface parts of a repository and auxiliary facilities),
- description of technological operations,
- detailed description of the site,
- preliminary safety analysis report for operational and post-closure period, and
- environmental impact assessment.

R&D required to support these documents address the principal issues, in particular they include:

a) design and construction of the underground rock characterization facility ONKALO

The main role of this underground facility is to allow for acquiring data that cannot be obtained by surface investigations. A significant part of the facility's total volume (330 000 m^3) will be a part of the future repository, therefore, its design, construction techniques and technologies and evaluation of their effectiveness and consequences, monitoring methodologies, development of QA/QC procedure and their implementing as well as management and co-ordination will be the main R&D topics.

b) design and technical development

Designing a robust disposal system is an important part of building confidence in the safety case. It requires minimization of all uncertainties, identification of potential detrimental processes and their avoidance, and a good understanding of safety-related phenomena to assure sufficient flexibility in developing the repository. Issues to be addressed include detailed site-specific design studies, encapsulation technology, canister development, repository technology, disposition techniques, excavation technologies, buffer/backfill development, sealing and closure of the facility, development of an alternative concept (horizontal emplacement), transport of spent fuel, and retrievability/reversibility.

c) developing the safety case

Based on the TILA-99 report [7.51], POSIVA is planning to draw up a planning report for the development of the safety case and update it continually both for vertical and horizontal emplacement concepts; a tight co-operation with SKB is assumed. Safety assessment itself will consist of three parts describing the initial state, the post-emplacement evolution and analyzing the release and transport of radionuclides. To provide for reliable results, clear requirements on data in all stages of repository development and evolution will be defined. A significant part of modelling is the identification and treatment of uncertainties, which is linked directly to understanding the evolution processes that may appear in the repository's engineered and natural systems.

d) increasing site knowledge and understanding

POSIVA set out the stages and objectives of the site characterization programme at Olkiluoto aiming at site confirmation [7.52]. Even if a substantial part of investigations will "go underground" and be associated with ONKALO, surface-based investigations will still play an important role, in particular with regard to the extension of the investigation area to identify a suitable host structure for the underground part of the facility. The techniques and technologies to be applied will go through all geological branches and will also include physico-chemical and geotechnical analyses. During investigations, data will be collected, processed and interpreted allowing for construction of descriptive models of the site. Based on this, three-dimensional geological, mechanical, hydrogeological and hydrochemical characterization of the rock mass and the associated groundwater system and relevant models will be prepared.

e) increasing the understanding of the repository near field

Near-field studies focus on the recognition of the post-emplacement evolution of the engineered barrier system (EBS). Specifically, they deal with evaluation of conditions external to canisters, canister deterioration processes, radionuclide release, retention and transport. Experiments could be performed in laboratories and confirmed/demonstrated in underground facilities - this allows for incorporation of these R&D activities into international co-operative projects. As a fair knowledge of basic mechanisms around canisters in the near field has been reached, the studies are concentrated on coupled effects, chemical site-specific interactions, material compatibility studies, gas and colloid formation. Evolution predictions of the canister itself are directed to quantification of mobilizing processes, such as material corrosion and dissolution. All these data provide inputs for determination of transport/retention properties and modelling radionuclide migration within EBS.

f) improving the understanding of far field processes

A knowledge base of retention and transportation processes will be developed by means of a combination of laboratory, generic and site specific experiments, supported by technical studies and modelling. Underground investigations will help with description of the geochemistry and hydrochemistry of the host rock and with a collection of the data needed for modelling impacts on the environment. This will be completed by biosphere studies aimed at determining the biosphere conditions at Olkiluoto, quantification of radionuclide migration through biosphere and consequent doses. Additionally, an impact on non-human biota will be studied.

JAPAN (a large programme in early development with no fixed schedule)

Japan, with 51 operational nuclear power reactors, belongs to the largest users of nuclear energy. Nuclear power provides nearly 1/3 of the country's demand [7.53]. The national strategy of spent fuel (SF) management relies on reprocessing, both in foreign and domestic capacities, and disposal of vitrified HLW. For repository studies, the total inventory to be disposed by the year 2015 is assumed to be 40 000 canisters. The repository is planned to be operational between 2033 and 2037 [7.54].

The Atomic Energy Commission of Japan (AEC) outlined the basic policy of HLW management [7.55]. According to the policy, HLW in solidified form will be stored for 30 to 40 years to allow for cooling and will then be disposed in a multibarrier facility built in a stable geological formation at a depth of more than several hundred meters. The Power Reactor and Nuclear Fuel Development Corporation (PNC), today the Japan Nuclear Cycle Development Institute (JNC), was authorized to co-ordinate research and development activities.

The AEC's Advisory Committee on Radioactive Waste Management (ACRWM) published a guideline document entitled "Major Targets and Methods of Implementation in Research and Development for the Geological Disposal of High-Level Radioactive Waste" in 1989. This guideline confirmed the appropriateness of the multibarrier system for geological disposal in Japan. The guideline stated that R&D should aim at demonstrating the feasibility of constructing an EBS appropriate to geological conditions in Japan. Additionally, assessing the long term performance of such a system should be demonstrated and, therefore, the applicability of geological disposal confirmed. The guideline:

- indicated a time horizon for summarizing the R&D results and its presentation to the general public and the scientific community (first report 1992, second report before 2000, then, after public and governmental review, carrying out the research)
- stated that regulatory bodies should develop the basis for safety standards followed by the issue of relevant regulations
- recommended establishment of an implementing organization by 2000 responsible, under Governmental supervision, for performing siting studies, site characterization, demonstration of disposal technologies, repository design, licensing, construction and operation

The recommendation brought into being the Nuclear Waste Management Organization of Japan (NUMO) in October 2000, based on the Specified Radioactive Waste Final Disposal Act. NUMO took over, among others, the co-ordination of the R&D in regard to geological disposal.

The first comprehensive progress report on R&D relating to geological disposal (“H3”) was published in 1992 [7.56]. This report confirmed that a sufficiently stable geological environment to ensure the performance of the multibarrier system could be found in Japan and that long term safety of this system could be ensured. It was approved by the ACRWM, which later issued new guidelines [7.57] requiring not only to demonstrate the technical reliability of the specified geological disposal in Japan, but also to provide a scientific and technical basis both for the siting procedure and for the development of an appropriate regulatory infrastructure (safety standards). This report indicated the specific topics that are to be addressed in subsequent R&D progress reports, including geoscientific studies, repository design and engineering technology, safety and performance assessments, scientific and technical bases for selecting a disposal system, transparency of review process, and a proposal of future R&D activities. Following the proposal, JNC set the following R&D objectives:

- to demonstrate that a suitable site for geological disposal can be found in Japan,
- to demonstrate that the disposal facility as a whole can be constructed using currently available engineering technologies, and
- to demonstrate that the performance of the geological disposal system, with the emphasis on the near field, can be reliably assessed.

The second Progress Report (“H12”), [7.54] was submitted to the AEC in 1999. In the review, issued the following year [7.58], it was stated that the technical basis integrated in H12 satisfied the technical requirements prescribed in the ACRWM guideline. The report contained a description of waste to be disposed, a basic concept of geological disposal, an overview of the Japanese geology, a discussion of potential design and an engineered system of the repository, an outline of performance assessment methodology, including some results of modelling, a discussion of technical basis for the selection procedure and the formulation of safety standards, a summary of arguments supporting technical feasibility of geological disposal in Japan and a proposal of major research and development to be performed in the future.

The strategy for R&D takes into account both institutional changes in Japan and research already performed. The facilities developed earlier and operated by JNC, such as the Engineering-scale Test and Research Facility (ENTRY) and the Quantitative Assessment Radionuclide Migration Experiment Facility (QUALITY), should play an important role in scientific support of the repository development as well as experiments carried out in foreign underground laboratories (in Canada, Sweden and Switzerland). Two national underground laboratories will become the main research facilities where technologies and designs will be demonstrated and data acquired. While the Horonobe underground research laboratory (URL) will study a sedimentary rock and saline water environment, the Mizunami URL will study granitic rock with freshwater. Modelling shall, among others, rely on data acquired from R&D programmes on analogue studies.

Key R&D goals required for implementation of geological disposal and relevant up to the stage of characterizing potential candidate sites were set out in the H12 report as follows:

- development of systematic methodologies for evaluating the stability of the geological environment for siting (case studies, development of technical criteria),
- verification of methodologies for characterizing geological environment specific to potential candidate sites (development of investigation/characterization methodologies and techniques, development of monitoring technologies),
- demonstration of engineering techniques (overpack fabrication, transport and emplacement, fabrication/emplacement of buffer material, backfilling technologies, repository construction),
- development of detailed numerical models and realistic databases for repository design (data acquisition, modelling of particular processes, development of models, development and optimization of engineered barrier system (EBS) materials),
- establishment of detailed design methodology (overpack design, measurement techniques, EBS integrity, rock mechanical stability, QC methodologies, guidance on seismic design), and
- improvement of assessment models and databases (radionuclide transport, overpack lifetime, extrusion of buffer materials, geochemical databases, biosphere model).

In Japan, R&D on partitioning and transmutation (P&T) technology is performed under the OMEGA programme (Options for Making Extra Gains from Actinides and Fission Products), which was initiated in 1988. P&T is not regarded as an alternative to geological disposal; it is considered to have a potential to reduce the volume, or to change the isotopic distribution of wastes to be disposed. Since 1999, the OMEGA programme has been also supervised by the ACRWM [7.46].

However intensive the national R&D programme, the role of international co-operation is well understood in Japan. Not only sharing experience in multinational projects performed in foreign facilities, but also plans to provide national R&D infrastructure for serving as the basis for international centres of excellence, are understood as important Japanese contributions to global scientific knowledge.

7.6 Topical Issue: Closure of a Surface Repository - La Manche

Near surface disposal of radioactive waste has been carried out for more than fifty years. There are more than 80 near surface repositories around the world [7.59]. Various Member States have ongoing programmes both to upgrade these facilities and to develop new near surface disposal facilities. Some repositories were or will be closed for different reasons: their capacity was exhausted, premature closure of a repository could be required either due to accidents (e.g., earthquakes, flooding, fires) or due to changes in public attitudes, demographic status, or the regulatory environment, a new national facility is put into operation, etc. Closure of a disposal facility is the last major operational step in completing the disposal system. Closure is defined as [4.12]:

> *administrative and technical actions directed at a repository at the end of its operating lifetime — for example covering the disposed waste (for a near surface repository) or backfilling and/or sealing (for a geological repository and the passages leading to it) — and* termination and completion of activities in any associated structures.

Repository closure is complete when the regulatory body confirms that the closure activities have been performed in an acceptable manner, that the appropriate documentation is available and that provision has been made for post-closure controls. In some cases, closure of portions of currently operational facilities occurs while the active operations continue on other parts of the facility. Partial or interim closure, particularly involving temporary or permanent vegetated caps and surface water management structures, can be beneficial in the sense that it would prevent or limit ingress of water to at least some parts of the facility [7.60].

An example of the recent closure of a surface repository is the Centre de Stockage de la Manche (CSM) situated at the north coast of France at Beaumont-Hague near Cherbourg [7.61]. The facility was put into operation by the Commissariat à l'Energie Atomique (CEA) in 1969. During the following decade, the design and technology evolved from simple disposal in earthen trenches to an engineered system with concrete trenches. Since 1979, CSM has been managed by ANDRA, the French National Radioactive Waste Management Agency.

Disposal was further improved by introducing standardized packages, a multibarrier concept, and a waste tracking system. By the end of its operation in 1994, the repository with an area of 600 x 300 m had accepted 527 214 m^3 of waste. Simultaneously with termination of disposal activities, a final cover was constructed (see Figure 7-1). Installation of the cover was completed in 1997.

Figure 7-1: Aerial View of Cover Work at Centre de la Manche

(source http://www.iaea.org/OurWork/ST/NE/NEFW/CEG/documents/ws102003_dutzer-e.pdf)

The cover is constructed so that the rainwater is diverted away from the repository. It consists of a bitumen membrane and of several layers of earth and sand (see Figure 7-2). It is equipped with a monitoring system for various purposes: stability control, visual observation of pipes, hydraulic control of the drainage systems located above and below the bitumen membrane, water-table control around disposal structures.

Figure 7-2: Cross-section of the Cover and Drainage Systems of the La Manche Repository

Turning the facility into the monitoring phase required both technical and administrative actions. In 1996, a public inquiry commission issued a favourable opinion concerning shutdown of the repository and the initiation of its post-closure monitoring phase. In 1997, the "Turpin commission" issued its opinion on the environmental impact. It recommended monitoring the facility in three phases:

- *very active surveillance, during which the evolution of the facility and the cover is followed:* Processes such as the consolidation of cover soil layers, changes in membrane integrity, the forming of cracks/fractures, and ground subsidence are investigated. Duration of this phase was set at five years. Whenever necessary, corrective measures are implemented and the performance model of the barrier system is validated.
- *active surveillance*: For a period of several tens of years surveillance will be carried out to ensure – with simplified of monitoring activities - that the performance of the disposal facility is consistent with designed evolution. It mainly includes controlling seepage-water rates and cover maintenance.
- *passive surveillance*: This phase will begin after demonstrating that ceasing active surveillance will have no major impact on the environment and knowledge of the site's nature and location will not be lost. During this phase the site will not be released for public use.

The Centre de la Manche was the subject of two public inquiries in 2000. The first was held from 2 February to 17 May and dealt with the authorization applications to move on to the monitoring phase, while the second, lasting from 2 February to 17 April, addressed the corresponding authorization application for liquid effluent releases. Once both inquiries were completed, the Inquiry Commission presented its report and conclusions to the Prefect of the Manche Department on 26 June 2000, and subsequently they were passed to the Nuclear Safety Authority.

The Decree of 10 January 2003 authorized the Centre de la Manche to enter into its monitoring phase. The terms and conditions for the monitoring of the facility are clearly defined. While the Order of 10 January 2003 renewed the authorizations for the releases of liquid effluents and prescribed their limits, it also imposed limits on certain radionuclides and on the toxic chemicals that were not regulated before. Those annual limits are equal to 0.125 GBq for alpha emitting radionuclides, 0.25 GBq for beta emitting radionuclides and 125 GBq for tritium.

7.7 Topical Issue: Upgrading of Near Surface Disposal Facilities

As stated in Subsection 7.6, near surface disposal of radioactive waste has been carried out for more than fifty years and there are now more than 80 near surface repositories around the world. Over that time, disposal methods have evolved and improved, with early approaches involving disposal of unpackaged waste in trenches and covered with locally excavated soil being replaced by emplacement of packaged waste in carefully engineered facilities and then covered by an engineered cover system of several metres thickness. The cover systems are typically composed of several layers designed to limit moisture infiltration and to control plant intrusion. The requirements imposed by regulatory authorities to ensure the protection of human health and the environment have also evolved over time [7.62].

Environmental monitoring, carried out within or in the vicinity of near surface disposal facilities, has in some cases indicated the need for corrective actions. These may involve changes in facility design, improvements to disposal unit covers or changes in operational procedures. In a limited number of cases, early closure of the repository and/or retrieval of specific wastes may be warranted. The corrective actions generally address one or more of the following objectives:

- to rectify of an existing unsafe condition,
- to prevent an unsafe condition from occurring in the future,
- to achieve compliance with modified regulatory requirements, or
- to respond to societal demands.

Corrective actions that have been implemented for repositories in IAEA Member States include:

- the formulation of new waste acceptance criteria and container specifications (e.g. Püspökszilágy (Hungary), Vaalputs (South Africa), Barnwell (USA), Richland (USA));
- building additional engineered barriers (e.g. Drigg (UK), Vaalputs (South Africa);
- installation of hydrologic cut-off walls (e.g. Drigg (UK));
- improvement of cover systems (e.g. Maišiagala (Lithuania), RADON facilities (Ukraine), Barnwell (USA));
- improved management control of leachate (e.g. RADON facilities (Russian Federation), Drigg (UK), Maxey Flats (USA)); and
- control of surface water run-off (e.g. Drigg (UK) and Maxey Flats (USA)).

In some cases waste has been retrieved from an existing facility, repackaged and disposed of at another site, e.g. at Solymár (Hungary) and at Kjeller (Norway). Retrieval of some waste is also planned to take place from other existing facilities, such as Püspökszilágy (Hungary), Maišiagala (Lithuania) and the Kiev RADON facility (Ukraine) [7.59], [7.62].

The process for implementation of corrective actions will typically include the following steps:

- *definition of initiating events*: These are the circumstances at a specific facility that may require corrective actions, such as premature degradation or failure of engineered barriers; discovery of waste-derived contaminants outside the containment barriers; non-conformance with existing operational procedures; or changes to regulatory requirements.
- *identify causes*: This requires an analysis of the underlying cause as well as the immediate symptoms of the problem. The ease with which such an analysis can be

undertaken depends on the degree of accessibility of the components of the disposal system (i.e. extensive investigations may be necessary when problems are indicated in already capped disposal units).

- *identify potential corrective actions*: A wide range of corrective action alternatives may apply to a particular circumstance, e.g. modification of waste acceptance criteria or operating procedures; repairing or upgrading the repository component causing the problem; enhancement of engineering barriers (waste form, waste packages and containment barriers within the repository), repair or remove leachate management systems; or reanalyze the safety case.
- *assess options and select preferred corrective actions*: Potential corrective actions need to be assessed in the context of all activities required to achieve the desired outcome, and ensuring that established safety standards are not compromised. Consideration should be given to the risks of actions versus inaction and to compliance with the applicable regulatory requirements.
- *develop corrective action plan*: This should define the sequence of processes and procedures to be followed while implementing the corrective actions (e.g. schedule and critical path, requirements for financial and personnel resources). The plan should also address supporting activities such as consultations with stakeholders.
- *implement plan*: The activities specified in the plan should be undertaken in coordination with the relevant regulatory authorities. Communications with other stakeholders, initiated during the planning phase, should be continued during implementation.
- *confirm effectiveness of corrective action*: The repository conditions prior to implementation of the corrective actions provide a basis against which the effectiveness of the corrective actions can be assessed. Typical indicators of the efficacy of the corrective actions include reduced radionuclide concentration in effluents, less leachate production, stable trench cover contours (indicating reduced subsidence), and reduced radiological contamination in the surrounding environment.

There are variety of circumstances that may require corrective actions of either a technical or a non-technical nature to be assessed or implemented at near surface disposal facilities. During the last decade, a large body of international experience has been gained regarding the application of corrective actions comprising a very broad range of possible activities, including improvements, upgrading, preventative actions, remediation, and intervention. This information will collected and assessed in a planned IAEA document (Application of corrective actions to near surface disposal facilities for radioactive waste).

7.8 Collection and Dissemination of Radwaste Disposal Information by the IAEA

The IAEA's Net Enabled Waste Management Database (NEWMDB, see Subsection 11.1) is used to collect information about waste disposal facilities in IAEA Member States. The intent is for the NEWMDB to be the most comprehensive source of information about waste disposal facilities and stored waste inventories. As discussed in Subsection 6.3.2, the results of the first two data collection cycles with the NEWMDB were published on the Internet and on CD ROM. Reports are accessible on line or can be ordered from the NEWMDB web site [2.3]. The third data collection was held March to July 2004 and the results were published on the NEWMDB web site.

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8 EXAMPLES OF EXISTING REPOSITORIES

The operation of near surface facilities for radioactive waste disposal has been practiced since the beginning of the nuclear industry more than 50 years ago. However, technical approaches to disposal have changed significantly over the intervening decades based on an improved understanding of both near and long term issues, advances in technology, and changes in political and public awareness of the issues at hand. These developments have lead to the specification of more stringent requirements for radioactive waste management and, in particular, waste repositories.

Advanced specifications were implemented for the current generation of repositories, such as Centre de L'Aube in France and El Cabril in Spain (see Subsection 8.1 in the third issue of this Status and Trends Report [2.4]). The designers of some repositories were required to address specific facility performance requirements, such as the development of:

- a repository for very low level waste (see Subsection 8.1, "The VLLW Repository in Morvilliers, France"), and
- a repository for "mixed waste" (USA classification, see Section 3) for radioactive waste containing toxic and/or hazardous substances (see Subsection 8.3, "The Clive Low Level and Mixed Waste Facility (Utah, USA)").

Some older facilities, specifically those that will be operated for several more decades, have had to be adapted to meet new requirements. This results in upgrading their structure, re-evaluating administrative measures and updating safety and performance assessments (see Subsection 7.7).

The remainder of this Section of the report includes four examples of existing repositories (three near surface and one cavern facility at about 50 m depth) that illustrate various aspects of the issues described above.

8.1 The VLLW Repository in Morvilliers, France

The future dismantling of nuclear reactors in France, see Subsection 5.3.2, raises the issue of the long term management of the decommissioning wastes that will be generated. The majority of these wastes will be produced following the progressive shut down of the 58 pressurized water reactors (PWR) currently in operation France. However, France is confronted with the dismantling of its nine gas cooled, graphite moderated NPP in the next 25 years (see page 48), the first waste treatment plant at Marcoule, as well as other installations, such as the CEA's research reactors and laboratories.

The general approach to managing decommissioning wastes is the same as for reactor operations wastes. However, the important issue to consider is the large volume of decommissioning wastes. The high activity range LILW and HLW represent a relatively small proportion, by volume, of the overall inventory. These wastes will be stored until suitable disposal is available. A dedicated storage facility is planned to be implemented by 2008-10 for radioactive graphite waste arisings (around 23 000 tonnes), which contain significant quantities of long lived radionuclides, even though the overall activity of this inventory is relatively low.

However, the largest volume of the future decommissioning waste inventory will be LILW with low levels of radioactivity. The higher activity range of these wastes will be disposed at the Centre de stockage de l'Aube (CSA), which has a capacity of 1 million m^3. The total inventory at CSA at the end of 2002 had reached 136 500 m^3 with an annual rate of waste arisings of 12-15 000 m^3. The facility was designed to handle an estimated 30 000 m^3 per year. The CSA should be capable of accommodating the arisings from the nine graphite reactors. It should also be capable of accommodating large waste items from these reactors.

Under French law, wastes produced from nuclear installations, where there is a possibility of them being contaminated, must be managed as radioactive waste (clearance is not an option). A large proportion of the waste inventory from the dismantling of the nine reactors (around 140 000 tonnes) is expected to have very low levels of radioactivity. In some cases, radioactivity is only suspected. It would, therefore, not be appropriate to dispose of these wastes at the CSA repository, based on safety and cost considerations. Therefore, France decided to implement the Morvilliers facility, a dedicated repository for this "TFA" wastes ("Très Faible Activité" is French for very low activity) [8.1]. See Figure 8-1.

Figure 8-1: The Morvilliers Very Low Level Disposal Facility

(source http://www.iaea.org/OurWork/ST/NE/NEFW/CEG/documents/ws102003_dutzer-e.pdf)

The requirements for environmental protection for TFA disposal depend upon the characteristics of the host site and of the geology in which it is located. These requirements particularly concern the containment characteristics of the host rock and the ease of hollowing out storage cells that have both long term stability and offer the potential for surveillance and inspection.

These criteria have led to the identification of a geological structure characterized by a thick layer of impervious clay, able to isolate the wastes from extreme water flows and sufficiently extensive for containing the inventory. The chosen site followed two geological characterization campaigns in 1999 and 2000 and is situated in a wooded area near Morvilliers, close to CSA. The clay layer is between 15 and 25 metres thick and is notable for its impervious and homogeneous character.

Agreement to create a repository for TFA at Morvilliers was reached following two public enquiries held in 2001 and 2002. The positive outcome of these enquiries allowed the last construction phase of the project to be completed prior to the opening of the repository in the summer of 2003 and the initial waste receipts in October 2003.

The acceptance criteria for TFA wastes are set out in general and technical specifications drawn up by ANDRA consistent with existing French legislation. These include the radiological and chemical characteristics of the wastes as well as the conditioning methods employed.

The Morvilliers repository represents an important waste management facility for the majority (by volume) of the wastes produced in France from the dismantling of nuclear installations. After the exploratory phase, provisionally 30 years, ANDRA will maintain a surveillance of the site and its environment for several further decades. At the end of the surveillance phase and after verifying the performance of the site, the site restrictions will be lifted.

8.2 The Drigg Low Level Waste Disposal Site (UK)

The Drigg site [8.2] (see Figure 8-2) is located on the West Cumbrian coast about 0.5 km inland and approximately 6 km to the southeast of the British Nuclear Fuels Limited (BNFL) Sellafield site. The total area of the site is about 100 ha. Until 1988, disposal was conducted solely by tipping waste into trenches, at which time disposal into an engineered vault (Vault 8) began as part of a general upgrade of the site. Trench 7 operations continued however until the start of operation of a high force compaction facility for LLW at Sellafield in 1995. The total area occupied by the trenches is about 16 ha and the total volume of emplaced waste is about 500 000 m^3. Due to the effects of self compaction in the trenches, about 800 000 m^3 of loose waste was actually emplaced.

Rail sidings were constructed at Drigg in the early 1980s to enable rail transfer of waste from Sellafield, significantly reducing traffic on local roads. Waste from non-Sellafield consignors, except that compacted in the facility at Sellafield, continues to arrive by road.

Site upgrade and current status

In 1987, a major upgrade of disposal operations at the Drigg site commenced with the principal aims of improving waste management practices, increasing the efficiency of space utilization and enhancing the visual aspect of disposal operations. The main features of the upgrade were:

- installation of a groundwater cut-off wall around the north and east sides of the trenches and construction of an interim cap over the completed trenches,
- refurbishment and enhancement of the leachate drainage system,
- phasing out of trench disposal of loose waste in favour of orderly emplacement of compacted, containerized and grouted wastes in engineered concrete vaults, and
- construction of new vaults.

Site closure

Following cessation of disposal, operational facilities will be decommissioned and long term site closure features constructed. Refurbishment work required during this period, for example to the drainage system or interim cap, will also be carried out. The site, its facilities and the environmental pathways will continue to be monitored.

The dominant feature of the closure design is leachate minimization. Leachate control is best managed by limiting the amount of water accessing the waste, optimizing the drainage provisions and maximizing dilution of residual contaminants released from the site before they impact upon the environment. This will be achieved through the combination of three main components of the closure system, namely a final cap, a cut-off wall and vertical drain.

Monitoring of the site

Throughout Drigg's operational and post-operational management phases there will be an ongoing monitoring programme. This has the objectives of both monitoring the environment on and around the site and monitoring the performance of the engineered structures including the site closure system. The engineering performance monitoring will include:

- the assessment of ground conditions in advance of construction of future vaults and the closure components in order to provide detailed geological, hydrogeological and geotechnical information for use in their detailed design;
- monitoring of site conditions during construction to ensure that the ground conditions encountered are within the design tolerances of the proposed structure; and

- monitoring of the performance of existing and future structures during both the operational and the post-operational management phases to confirm compliance with their design and that their performance is acceptable.

Figure 8-2: Aerial Photograph of the Drigg site (viewed from north-west to south-east)

(Source: BFNL Online Asset Library: http://www.bnfl.com/library/upload/summary.aspx?asset=865#)

Controls over the site at the end of its use

Subject to a final assessment, the site is expected to be closed as a disposal site. At this stage, an institutional control phase would commence. The duration of this phase is expected to be tens to hundreds of years.

8.3 The Clive Low Level and Mixed Waste Facility (Utah, USA)

The Clive facility [8.3] is located in a remote, arid climate within the Tooele Hazardous Industry District of Utah State, more than 20 miles from the nearest sources of drinkable water. It is located adjacent to a major rail line and Interstate Highway 80, enabling waste deliveries both by road and rail. The facility has the following main characteristics:

- approximately 18 cm annual precipitation,

- over 150 cm annual evapo-transpiration,
- low-permeability clay soils,
- more than 70 km to nearest population centre,
- groundwater naturally unsuitable for human use, and
- stable geology.

The facility consists of several above ground, engineered disposal cells (Figure 8-3), designed to receive the following waste streams:

- debris waste - comprising:
  - regular debris (compacted to 90% of its optimum density in order to minimize the possibility of void formation that may in turn compromise cell integrity through settlement), and
  - oversized debris (in terms of density or volume) - these materials are either surrounded by soil that is compacted to eliminate voids or are surrounded by fill material to create a monolithic form to fill the void spaces.
- oversized debris (in terms of density or volume) - these materials are either surrounded by soil that is compacted to eliminate voids or are surrounded by fill material to create a monolithic form to fill the void spaces,
- NORM waste - shipped by rail and emplaced in the engineered cells in bulk form; the total available capacity is 1.5 million m^3,
- low level radioactive waste - comprising Class A waste (USA classification, see Subsection 3), under the terms of a licence granted by the State of Utah, and
- by-product material (USA classification, see Subsection 3) - certain mixed wastes are accepted for direct disposal at the facility.

<u>Mixed Wastes</u>

The Clive facility is the sole commercial mixed waste (USA classification, see Subsection 3) disposal facility in the US, having received a Resource Conservation Recovery Act Part B Permit in 1990. Under this permit, the facility receives and disposes of waste that is both low level radioactive (USA classification, see Subsection 3) and hazardous. These solid mixed wastes may include: soils, soil-like wastes, debris, dried process sludges, solid process wastes, Comprehensive Environmental Response, Compensation, and Liability Act response action wastes, NORM hazardous wastes, mixed wastes from industrial processes, treatment residues, and others.

The Mixed Waste Facility has indoor and outdoor temporary container storage areas. These areas are used for material holding while samples are sent to independent laboratories for analysis.

<u>Design and development of disposal cells</u>

All disposal cells are designed to provide shallow disposal of waste. Waste is placed in 300 mm thick layers then compacted to required density specifications in a continuous ‘cut and cover’ process. The continual building, filling, and capping of cells are intended to ensure long-term cell stability.

<u>Cell liner systems</u>

Each cell liner system is specifically designed to support the type of waste to be disposed. A cell bottom liner consisting of a compacted, ~0.6 m layer of low-permeability clay covers a foundation of compacted indigenous clay and soils. The mixed waste disposal cell is designed with three synthetic liners of high-density polyethylene. The liner system consists of mixed waste leachate collection and leak detection for each synthetic liner.

<u>Cell capping</u>

The cell embankment top slopes are covered with a compacted seven-foot thick clay cover, a rock filter layer, and a two-foot thick rock erosion barrier to provide long-term protection of the environment.

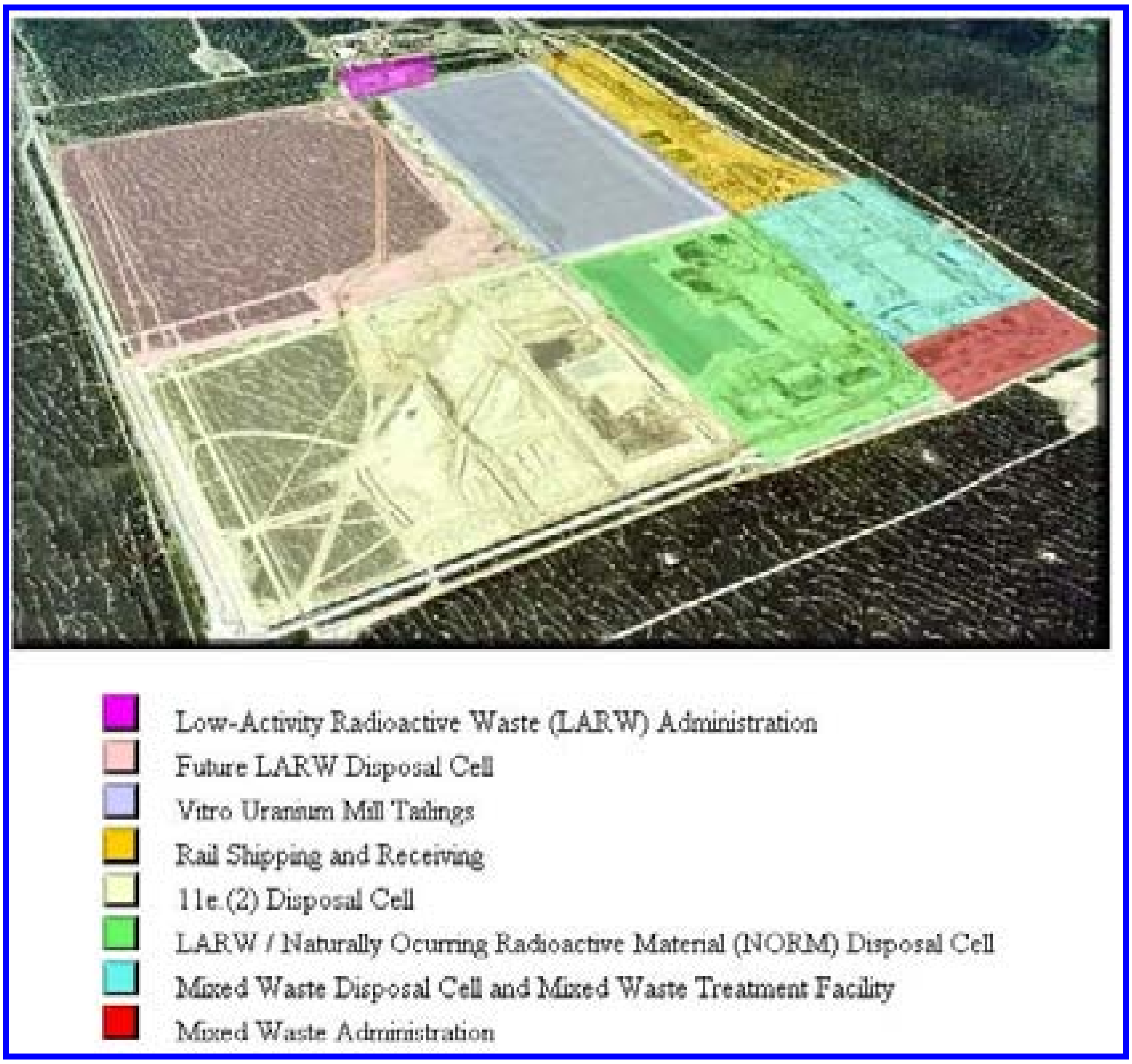

Figure 8-3: Layout of the Clive Disposal Site

8.4 Richard Repository – Underground Caverns (Czech Republic)

The Richard repository [8.4] is situated in a former limestone mine near the town of Litomerice (60 km NW of Prague). The mine consists of more than 40 km of galleries and passage ways. Chambers and corridors, adopted for use as a disposal facility in a separate part of the mine complex were excavated in a thin (3 - 5m) layer of limestone some 40 - 60 m below the surface. This layer is insulated from top and bottom by 30-60 m layer of water impermeable marlstone (hydraulic conductivity is $3x10^{-9}$ - $4.9x10^{-11}$ $m.s^{-1}$).

Although generally dry, the mine is infiltrated by rainwater at several places. This water is collected in a drainage system running along the access gallery and, after being monitored, it is released to the environment. The underground water table is approximately 50 m below the disposal level in a sandstone formation. The temperature and relative humidity in the repository is essentially constant at 10°C and 95% respectively. To support mechanical stability of the mine, a reinforced concrete frame was installed at the most exposed places (see Figure 8-4).

Figure 8-4: The Main Access Gallery of the Richard Repository

The total volume of available underground spaces exceeds 17 000 m^3. The present gross volume of the chambers for disposal of radioactive waste is approximately 9 950 m^3 and the estimated volume of radioactive waste that could be disposed of is about 5 500 m^3. By 2003, about 62% of this capacity was used. The radioactive inventory of the waste is summarized in Table 8-1.

Table 8-1: The Radioactive Inventory in the Richard Repository as of 2003

Nuclide	Total inventory limit	Drum activity limit (200 litre drum)	Total disposed of inventory	% of limit	The highest activity of any drum disposed	% of limit
	[Bq]	[Bq]	[Bq]	%	[Bq]	%
^{3}H	1.00E+15	1.00E+13	5.794E+13	5.79	7.001E+12	70.01
^{14}C	1.00E+14	3.00E+10	7.223E+12	7.22	3.380E+08	1.13
^{90}Sr	3.00E+14	3.00E+11	3.262E+12	1.09	4.891E+09	1.63
^{137}Cs	1.00E+15	6.00E+11	4.201E+14	42.01	3.649E+10	6.08
alpha	2.00E+13	1.00E+08	1.400E+13	70.01	9.943E+07	99.43

NA = not applicable

Since 1964, radioactive waste from institutional applications has been disposed in the Richard repository. Waste acceptance criteria were changed several times since repository commissioning based on legislative requirements valid at the time. Simple waste packages were used in the early stages of operation. There is a lack of detailed information on the packages disposed of during the 1960’s and 1970’s. Most waste was in steel drums (50, 60, 80, 100, or 200 litre capacity).

In the 1990’s, “sandwich construction” was developed for non-solidified waste consisting of a 100 litre drum grouted into a 200 litre drum. With this method, a 5 cm thick concrete barrier surrounds the waste in each package.

Waste packages are placed into chambers, some of which are closed with simple walls without provision for access or active control of their physical or radiological properties. Spaces between packages not filled (see Figure 8-5).

Figure 8-5: View of a Disposal Chamber in the Richard Repository

The repository has operated for almost 40 years without accident, but it needs systematic maintenance and upgrading as its operation will continue for decades. The following lists the main improvements that have been completed recently:

- mine reconstruction (conservation of underlying structures, mine entrance, ventilation, lights, electric supply),
- surface are reconstruction and upgrading (new administration building with an information centre, new fences, refurbished hot cells and operations building, road resurfacing),
- radiation protection (new monitoring programme and measuring devices, controlled zone regime),
- records (extension of record content with tracking, conditioning and chemical properties data), and completion of additional hydrological investigation and updating of the Safety Report for the repository).

Further upgrading will focus on the following issues:

- adoption of two chambers for accepting dimensionally non-standard waste arising during refurbishment and decommissioning of radioactively contaminated laboratories,
- reconstruction of a hot cell for conditioning disused sealed sources,
- design and demonstration of sealing a chamber (methodology development to demonstrate a feasibility of safe closure of disposal chambers, specification of appropriate filling materials and a proposal of adequate implementation technology for closing the repository), and
- introduction of new waste acceptance activity limits (see Table 8-2).

Table 8-2: Radionuclide Acceptance Criteria for the Richard Repository since 2004

Radionuclide	Activity of bulk waste [Bq/kg]	Activity of non-conditioned waste in sandwich type packages [Bq]	Activity of conditioned waste in 200 l drums [Bq]	Total inventory limit [Bq]
^{3}H	3.10^{9}	1.10^{12}	1.10^{13}	1.10^{15}
^{14}C	1.10^{7}	3.10^{9}	3.10^{10}	1.10^{14}
^{36}Cl	3.10^{6}	1.10^{8}	1.10^{9}	1.10^{12}
^{90}Sr	1.10^{8}	3.10^{10}	3.10^{11}	1.10^{14}
^{99}Tc	1.10^{5}	5.10^{7}	5.10^{8}	2.10^{11}
^{129}I	1.10^{4}	2.10^{6}	2.10^{7}	2.10^{8}
^{137}Cs	1.10^{8}	3.10^{10}	3.10^{11}	1.10^{15}
Total activity of long lived alpha-emitting nuclides	3.10^{4}	1.10^{7}	1.10^{8}	2.10^{13}

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8.3 Envirocare, “Tour Envirocare’s Treatment and Disposal Facility” http://www.envirocareutah.com/pages/educate/tour/tour.php

8.4 Radioactive Waste Repository Authority (Czech Republic), “Information on Repositories” http://www.vidivici.cz/surao2/index.php?c=86&s=tisk

9 THE MANAGEMENT OF SPENT/DISUSED SEALED RADIOACTIVE SOURCES

Previous issues of this Status and Trends report identified problems associated with the management of sealed radioactive sources (SRS). In particular, concerns were expressed regarding SRS that are taken out of service (disused or spent SRS) and for which no proper management system exists. It was pointed out that accidents with disused or spent SRS account for a significant proportion of all radiation accidents and they can lead to severe injuries or death.

Issue 1 presented the basic concepts for SRS management per the requirements of Article 28 (Disused Sealed Sources) of the Joint Convention [2.1]. Under Article 28, two requirements must be addressed:

- the Contracting Party must demonstrate that the possession, remanufacturing, or disposal of disused sealed sources takes place in a safe manner, and
- the Contracting Party permits disused sealed sources to re-enter into its territory to a manufacturer qualified to receive and possess the disused sealed sources.

Issue 1 concluded that effective national regulatory systems, implemented by knowledgeable people, are the key to preventing accidents with SRS. Such systems must:

- include rigorous control of the SRS inventories,
- ensure the adequate planning of actions to be carried out in the event of loss of control of an SRS, and
- the capability to carry out such actions.

Issue 1 also pointed out that the safe disposal of disused sources is basically a national responsibility.

For countries that have no disposal facilities, safe disposal may require transferring disused/spent SRS to another country - normally the country of the supplier - that has the infrastructure to dispose of them safely.

Issue 2 described ‘The Borehole Disposal Concept” and provided an update of the compilation of data for the “International Catalogue of Sealed Radioactive Sources”.

Issue 3 provided overviews of SRS management in various countries (Argentina, Belarus, Chile and USA). It also included a discussion of the “Proposed EU Directive on Orphan SRS” and an overview of the work of the SRS Task Group of the Forum for Nuclear Cooperation in Asia.

This Section of the current issue of the Status and Trends report:

- discusses the return of spent/disused SRS to suppliers (see Subsection 9.1),
- discusses the development of a mobile installation for handling sealed high activity radioactive sources (SHARS) (see Subsection 9.2),
- provides examples of Member State programmes and experiences with SRS management (see Subsection 9.3), and
- describes and provides examples of IAEA assistance to Member States in the area of SRS management (see Subsection 9.4).

9.1 Topical Issue: Return of Sources to Suppliers

9.1.1 Background

Every year a significant number of radioactive sources are found to be out of administrative control. The IAEA is aware that spent/disused SRS pose a risk that needs to be minimized and avoided in order to protect the public and the environment against undue exposures. The IAEA included spent/disused SRS within the scope of its programmes to assist Member States to cope with this problem, provide technical solutions and support medical diagnosis or treatment in the case of accidents.

The "Action Plan" [9.1] approved by the IAEA's Board of Governors and the General Conference of the IAEA, lists several initiatives to cope with the problem of spent/disused SRS.

Work to gather opinions and experience with the management of SRS, in particular, the return of spent/disused SRS to suppliers (which includes manufacturers), is currently on going at the IAEA and a number of significant sources have already been returned to their suppliers.

The return of a source to its supplier is always a preferred option. Many manufacturers can accept returned sources for disposal but, in many cases, reuse or recycling of sources is also feasible. The IAEA has contacted several source manufacturers and received positive feedback on this issue. Return of spent/disused SRS to suppliers is being investigated and evaluated in different aspects, namely technical, economic, administrative/legal/regulatory and public acceptance. A short summary of these aspects is presented next.

9.1.2 Technical Aspects

The return of a source to a supplier, especially for reuse or recycling, can depend on many technical factors. Proper design characteristics are essential including physical specification, chemical composition, the encapsulation material containing the source and the welding process. Source design should consider the requirements of reuse/recycle and disposal at the end of a source's life. This consideration was not fully applied at the design and manufacture in the past, resulting in difficulties in the management/recycle of spent/disused sources today. The technical features of a source have a significant impact its working life, involving economic consequences as well. It is worth mentioning that there is no uniform, industry definition for the recommended working life of a source.

Beyond the need for continuous improvement of the physical and chemical properties of SRS, another important issue is to develop the manufacturers' preparedness to accept more sources for reuse and/or recycling. This issue includes technical preparedness and support to customers, which can stimulate user interest in the return of sources to suppliers. Distinct documentation (source certificate), good and reliable labelling of the source and the shield, as well as the availability of a licensed container are factors increasing the chances for return. These factors are missing or weak in many cases, leading to major problems in the "back end" of SRS management.

9.1.3 Economic Aspects

The cost of returning sources to suppliers is not usually considered when a source is being sold to a user. Cost is an important factor in every case when a source is being returned to a supplier. The main question is who will cover the expenses, although this has not yet been answered in numerous cases. The significant economic challenges of dealing with "orphan sources" are well recognized and this encourages all stakeholders to find a solution. It is clear that the effective and reliable management of spent/disused SRS, including return to suppliers, costs less than dealing with the consequences of accidents. Experience to date has shown that this issue requires international collaboration.

9.1.4 Administrative, Legal and Regulatory Aspects

The accidents that have occurred with SRS have shown that they originated, to a considerable extent, from the loss of administrative control over them. Disuse of a source, caused by either bankruptcy or simply the closing of a user's facility, increases the risk of mishandling, disappearance of the source and, thus, loss of control. Stakeholders should enhance their activities to upgrade the legal and administrative conditions needed to control SRS during their working time and to take the required technical steps to retire the source properly and prepare (condition) it for the intended purpose (return to supplier, long term storage, reuse, etc.). Difficult issues need to be addressed, such as transportation, re-licensing of the sources ("special form certificate" issue), etc.

9.1.5 Public Acceptance

This is an additional, but very important issue, for the return of sources to suppliers. General public opposition to the movement of radioactive materials through regions or countries should be considered. Mitigation of problems can be facilitated if the IAEA, together with all partners involved, provide clear information to the public that demonstrates the safety advantages of returning a source to its supplier/manufacturer compared to the risk of dealing with uncontrolled or orphaned sources.

9.2 Topical Issue: Mobile Installation for Handling Sealed High Activity Radioactive Sources (SHARS)

Technological developments and higher quality assurance requirements in various fields have led to a substantial increase in the number of SRS being utilized in various disciplines. The number is estimated to be in the order of several millions, both in and out of use. This makes the risk of a source related accident high, even if the probability of an accident from an individual source is relatively low.

The sources of most concern are the ones that are no longer in use. The terms spent, orphaned and disused are used among others to mean that the source is no longer utilized for its intended purpose. Sources that are addressed in this subsection of the Status and Trends report are all ***S***ealed ***H***igh ***A***ctivity ***R***adioactive ***S***ources (SHARS).

The management of spent/disused SHARS is inadequate in many developing countries. In many cases, the lack of an appropriate infrastructure and the lack of a technical capability means there are SHARS for which no adequate management framework exists. This is mainly due to the expiry of the Special Form Certificate and/or the unavailability of a licensed transport container. Most of these sources are either teletherapy sources or radiography sources that currently have an activity of 2 – 4 TBq (500-1000 Ci). Such sources pose a real risk for a long time to come and have been the cause of many accidents. Their status, with nothing being done, can only get worse.

High costs prohibit the transfer of these SHARS to conditioning facilities. To build a suitable facility in each country is too expensive and it cannot be done in a reasonable time.

In recognition of the above situation, the IAEA issued a technical document on the management of SHARS [9.2]. The report provides guidance on the technical, administrative and economic issues associated with SHARS from the moment they cease to be in use through to disposal, including transport, conditioning, interim storage, and storage (see Subsection 6.4 for the definitions of interim storage and storage). Detailed rules and regulations for transport are outside the scope of the document but relevant transport documents are referenced. The SHARS document is within the scope of the Action Plan (see Subsection 9.1.1).

In addition to the SHARS guidance document, steps are being taken to provide direct assistance to Member States to deal with their SHARS. When the IAEA's technical procedures for handling radium sources were prepared and tested, a mobile set of equipment was designed, manufactured or simply purchased and teams in different regions of the world were trained to conduct conditioning operations for radium sources. The programme proved to be successful and lessons learned from the programme are of direct relevance to the SHARS issue. While the set of equipment, the technical procedures and the QA programme for conditioning of the SHARS sources will be more extensive, the radium conditioning programme provides a unique experience that is relevant, especially in the implementation stage. The programme of SHARS conditioning can also be implemented using a set of equipment that can be easily transported to the country along with an expert team to conduct the work.

The obvious solution to the problem is to condition the sources in such a way as to make their long term storage in a designated facility, their transport across borders to the original manufacturers or to a waste operator in a developed country both possible and safe. This would require that the source be re-certified as a special form radioactive material and that a licensed transport container be available.

The required infrastructure and the qualified personnel for such task are not available in most developing countries. Innovation in the design of the necessary equipment and the development of technical procedures will be required, so that technology used on a day-to-day basis in developed countries can be adopted for use in developing countries requiring assistance. International cooperation would be indispensable to put such a solution into practice.

9.3 Examples of Member State Programmes and Experiences with SRS Management

9.3.1 SRS Management in Sudan

based on input provided by Mr. I. Shaddad
Sudan Atomic Energy Commission

Introduction

Sealed sources are being used extensively in different nuclear techniques. In agriculture, Cs-137 and neutron probes are being used for soil density and mositure determination. In medicine, they experience extensive use in cancer treatment. Sealed sources have become an important tool for quality control in industry for non-destructive testing (NDT). This is the case for the oil industry and in the transportation sector in general. Sealed sources are also used for research and education.

Spent and disused sources from various applications, in many cases, are active enough to expose the public and workers to significant radiation doses. In developing countries, management of these sources is a costly process. Financial constraints and the availability of technical capabilities are the main factors affecting the implementation of a program for the collection, treatment, conditioning and storage of sealed sources. Other factors, the like lack of sufficiently trained personnel and inadequate legal frameworks and/or regulatory environments also have negative impacts on a waste management programme.

In Sudan, the Department of Radiation Protection & Environmental Monitoring (DRPEM) of the Sudan Atomic Energy Commission (SAEC) is responsible for the management of radioactive waste. A waste management facility was established by SAEC in Soba in 2000. It consists of a laboratory for waste treatment, a cementation area and a storage area for conditioned and unconditioned spent/disused SRS.

Inventory of SRS

Source registration started in 1996 [9.3] and, currently, 501 sources are registered (about 80% of sources in Sudan). Table 9-1 shows the number of sources registered in different applications. Details of these sources are shown in Table 9-2 and in the text that follows the table.

To assist the registration process, the DRPEM sent letters to the institutes that have radiation related activities (20 institutes). Each institute was requested to appoint a technical person as a radioactive material coordinator and to present a list of the radioactive sources in its possession. The DRPEM sent inspection teams to these institutes for source search and identification.

Export/import movement of SRS is reasonably controlled through good collaboration with the customs department. Customs officers were trained in using radiation monitors for detection of unauthorized/unlicensed sources that may enter the country.

In the last 4 years, intensive work started in the oil industry in Sudan. This activity has resulted in a greatly expanded use of radioactive sources for industrial radiography. According to the sealed sources registry, the number of industrial sources amounts to about 70% of all sources in use in the country (excluding Ra needles).

Table 9-1: Number of Sources Registered in Sudan and Returned to by Application

Field	Number of sources
Industry	129 (18 returned to supplier)
Medical	26 (+ 319 Ra – sources)
Research	27

Table 9-2: Details of Registered Sealed Sources in Sudan and Returned to Supplier

Source	Total No.	No. in use	No. out of use	No. returned to supplier	Management done
Th-228	1	1			
Fe-55	2	0	2		
Neutron sources	49	33	16		16 (collected)
Cs-137	63	58	5	9	5 (collected)
Ir-192	33	30	3	9	3 (collected)
Co-60	17	12	5		3 (collected)
Sr-90	10	5	5		5 (collected)
Co-57	7	0	7		
Ra-226	319	0	319		319 (conditioned)
Total	501	139	362	18	

Ra-226 Sources: Ra-226 needles and rods acquired in 1967 for use in radiotherapy. The total amount of Ra in Sudan is about 1 gm (319 needles). Conditioning of Ra sources was carried out in March 2000 with IAEA assistance. Two waste drums were produced, SUDI and SUD2, each contain 500 mg of Ra. The two drums are being stored at the SAEC waste management facility in Soba.

Disused Neutron Sources: Neutron sources are used in agriculture and for oil exploration. To date, 16 disused neutron sources have collected and are safely stored in the Soba waste management facility. These sources contain long lived radionuclides and their long term management is a problem for Sudan. The only viable option is to return them to their manufacturer (discussed later in this subsection). This option can only be implemented with IAEA assistance.

SHARS: The technology and experience required to remove SHARS from the equipment that contains them does not exist in Sudan. These sources have remained in the operations rooms at their users' premises for more than 30 years without a plan for their long term management. With the assistance of the IAEA, the three SHARS listed Table 9-3 were collected and are stored in the waste facility at Soba. Further management options are needed for these sources.

Management of Disused Sources from Industrial Companies

Companies carrying out NDT imported a large number of Ir-192 sources for quality control of welding. The waste management unit of the DRPEM started to collecting Ir-192 sources from a limited number of these companies and stores them in lead containers, or with their shielding, in the Soba facility. Difficulties associated with this service includes the limited availability of lead shields and proper handling equipment. Also, there is difficulty in quantifying the costs for conditioning and storing sources. All sources collected or conditioned at the facility had belonged to the public sector or were orphan sources.

Table 9-3: Inventory of SHARS in Sudan

Source	Place	Type	Activity now	Origin
Gamma cell Co-60	Faculty of Agriculture U of K	Irradiator From India	50 Ci	IAEA project (1978)
Gamma cell Co-60	Veterinary Res. Center	Irradiator from India	50 Ci	IAEA project (1974)
Teletherapy unit Co-60	RICK	Teletherapy Britain	500 Ci	Donation from Britain

Return of Disused Sealed Sources to Supplier

An option for the management of Sudan's spent/disused sealed sources is to return them to their supplier or manufacturer. This option has been used for recently imported sources, especially with those provided by foreign companies. This is usually done by a written undertaking with the company to return the source after use. However, in many cases it is difficult to apply this procedure to the local companies due to the high charges levied by the manufacturer to accept the source as waste.

Waste Management Equipment and Training

Before 1998, no equipment was available in Sudan to manage spent/disused SRS. Through IAEA regional project RAF/4/015, "Strengthening Radioactive Waste Management Infrastructure in African Member States", equipment and training were provided by the Project. As a follow up, the Sudanese national team carried out conditioning of seven Cs-137 and four Sr-90 sources. Sources were conditioned by cementing them in 200 litre drums.

Four staff members from the SAEC are dealing with radioactive waste management. All of them have been trained through the IAEA training courses and workshops under regional and interregional programs.

Waste Management Facility

Due to the increase in the number of spent or disused sealed sources registered, as well as the number of accidents from orphan sources around the world, the SAEC established the Soba waste management facility (about 15 km from Khartoum). The facility was commissioned in February 2000. It consists of a laboratory of about 5 m x 8 m and on the same floor level, about 4 m apart, a small store of about 4 m x 4 m. The area in-between the laboratory and store is a cementation area for cementing waste in drums. Figure 9-1 shows the layout of the facility.

The facility is being used for the management and conditioning of low level waste (LLW, Sudanese classification – see Section 3), mainly sealed sources (industrial, medical, research etc.).

The DRPEM of SAEC collects disused sources from users and transfers them to the waste management facility. Registration, measurements and segregation are done inside the laboratory. The facility is equipped to recover the waste for conditioning by cementation in 200 litre drums. Sealed sources were conditioned with their shielding container. The maximum loading activity for each drum is 40 GBq (10 Ci).

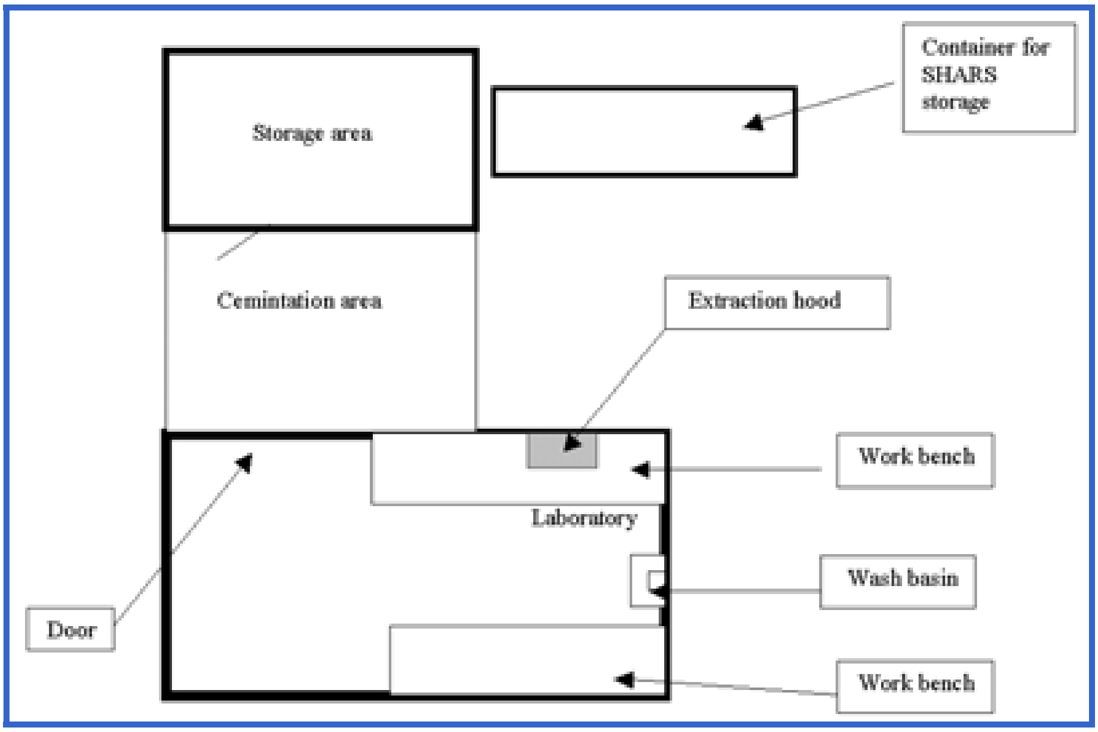

Figure 9-1: DRPEM Waste Management Facility Layout

<u>Problems facing SRS Management in Sudan</u>

<u>Source Inventory</u>

It is believed that the number of sources registered represent about 80% of the sources in the country. Waste management started 30 years after Sudan introduced nuclear techniques in a number of areas. The expansion in industrial radiography recently led to an increase in the number of imported sources. Control of industrial sources is not adequate; there are problems pertaining to licensing of all imported sources. Some factors include lack of experience in developing and improving licensing forms and applications, which need to be made more restrictive and informative.

<u>Neutron Sources</u>

Neutron sources and probes are being used in Sudan for education, agriculture and water research. Recently, oil companies for oil exploration have imported a number of neutron sources.

Based on an SAEC survey, in most cases after sources were used they were left in the field without physical protection. The majority of these sources had no documentation. For the 16 neutron sources identified, collected and stored in the DRPEM waste management facility, their conditioning remains an important issue that needs to be resolved.

<u>Disposal of Spent/Disused SRS</u>

All spent/disused SRS collected are stored in the DRPEM facility. A disposal facility is neither currently available nor is there a disposal programme in place. This is due to the lack of experience and resources to plan for a disposal facility.

Figure 9-2 illustrates some aspects of SRS management in Sudan.

Co-60 Irradiator (a SHARS) collected in Soba

Teletherapy head collected from RICK hospital in Khartoum

Waste Management facility in Soba

Neutron Sources collected at the waste facility in Soba

Figure 9-2: Some Photographs of SRS Management in Sudan

9.3.2 Disused SRS Management in Cuba
based on input provided by Mr. J-C Benitez-Navarro and Ms. M. Salgado-Mojena
Center for Radiation Protection and Hygiene (CPHR),
Havana, Cuba

Introduction

Sealed radioactive sources are widely used in Cuba in industry, medicine and research. Once SRS are no longer in use, they are declared disused.

Disused SRS represent a large waste problem in most developing countries. Improperly controlled and stored, such SRS have caused a number of accidents around the world [3.10]. Some of these accidents resulted in human deaths and/or contamination of large areas. In order to reduce risk, the first priority would be to bring disused SRS under appropriate controls. It is important to have a proper infrastructure in the country for their safe management.

The Center for Radiation Protection and Hygiene (CPHR) is responsible for centralized collection, transport, conditioning, storage and disposal of disused SRS in Cuba. For SRS containing radionuclides with half lives of 30 years or more, deep geological repositories offer the highest level of isolation within disposal concepts currently considered [9.4]. However, such facilities are extremely expensive to develop. It is unlikely that such an option will become available in the foreseeable future for most countries, particularly for those like Cuba, which do not have nuclear industries. The safe, long term management of disused SRS for these countries remains an open question.

Inventory of Disused Sealed Radioactive Sources In Cuba

An updated inventory of all stored wastes and disused SRS is kept at the CPHR. The current inventory of stored disused SRS is presented in Table 9-4.

Table 9-4: Inventory of Disused SRS in Cuba

Disused SRS	**Estimated number of SRS**
MEDICAL	
Radiotherapy - Teletherapy	26
- Brachytherapy	2000
INDUSTRIAL AND RESEARCH	
Industrial radiography	77
Irradiation facilities (industrial and research)	1
Industrial gauges	551
Well logging	37
Analytical techniques (industrial and research)	57
OTHER PRACTICES	
Lightning rods and smoke detectors	9870
Sources used for teaching	168
Calibration sources	1570
Detectors for icing on aircraft	200

Conditioning of Disused SRS Prior to 2001

Originally, the approach for conditioning disused SRS was developed to remove sources from the human environment and make them inaccessible to humans. The recommended methods of conditioning disused SRS were simple and adequate. Two hundred litre drums were filled with concrete with a cavity in the centre. Disused sources, with their radiation shielding, were successively placed in the cavity until either the cavity was filled or until a limit of activity had been reached (see Figure 9-3). Next, cement mortar was poured over the sources [9.5] to [9.7]. By this procedure, 11 drums with 88 disused SRS were conditioned. At present, leaking SRS are the only ones conditioned by cementation since retrieval of SRS from the packages is not envisioned.

Figure 9-3: Conditioning of Disused SRS in Cuba

Conditioning of Disused SRS After 2001

Due to the high cost of disposal, SRS conditioning for storage should take possible changes to repository waste acceptance criteria into consideration. Furthermore, conditioning by embedding in concrete may be counterproductive with regard to efficient utilization of repository space. Consequently, any conditioning process for storage should allow retrieval of SRS from storage packages for future handling/conditioning without imposing undue cost.

The majority of Cuba's disused SRS has been conditioned to allow retrieval. Instead of filling the drum cavity with mortar after emplacing the SRS, two iron bars are welded onto the upper part of the drum and the lid is then placed on and locked. The procedure is similar to that described in an IAEA technical document on the conditioning and storage of spent radium sources [9.8]. Between February 2001 and December 2003, 1092 disused SRS have been conditioned in 142 drums.

Conditioning of Disused SHARS

High activity gamma sources, usually contained in heavy shielding devices, are not be suitable for conditioning by traditional methods. For such sources, the only management option, except returning them to their manufacturer, is to retain them in their shielding devices in storage (likely for several decades) awaiting future management options.

Figure 9-4 illustrates conditioning options for disused teletherapy sources within their working shields. The three photographs in the top row of the figure show different sources within their shields. The left and centre photographs in the bottom row show options for emplacing the sources, within their shields, in overpacks. The right most photo in the bottom row shows radiation checking outside the waste packages.

Prior to closing packages, iron bars are welded across the tops of the packages to secure the sources. Afterwards, the container is covered with a lid secured with screws to prevent unintentional and unauthorized opening. Closing and locking the container concludes the conditioning process. Sources are therefore stored in a safe, secure and manner. By this method, 16 disused SHARS were conditioned.

Storage of Disused SRS – Record Keeping

A national storage facility for conditioned radioactive waste and disused SRS was developed to manage these wastes until the time that a repository is available. The storage facility is located in a sparsely populated region, 25 km from Havana city. The facility is within an above ground, earth-covered mound. The estimated capacity of the storage facility is about 200 m^3 [9.9]. See Figure 9-5.

A record keeping system for tracking waste, including SRS, has been established. The information is reliably stored and archived both manually and by a computerized database. For SRS, information includes the source model, identification numbers (source and container), radionuclides, activity and reference date, manufacturer, former user, and storage location. This information was obtained by measurements, interviews, and consulting documents. Other sets of data, defining the characteristics of each conditioned package, is registered and kept before this package is stored for long periods. Data include the package identification number, activity content and reference date, the number of sources conditioned, surface dose-rate, dose-rate at 1 meter, contamination level and date of measurements, date and place of conditioning, conditioning method, and the person(s) who carried out the conditioning.

Cuba has addressed the uncertainties of conditioning disused SRS in the absence of waste acceptance criteria for disposal by ensuring that disposal in the future is not hindered by actions taken in the near term. All disused SRS are packaged in passive, safe, monitorable and retrievable storage. Options are fully left open for future solutions.

Figure 9-4: Teletherapy Source Conditioning

Figure 9-5: Waste Packages in Storage in Cuba

9.4 Examples of IAEA Assistance to Member States

9.4.1 Source Recovery/Conditioning in Thailand

Funding support from the IAEA's Technical Cooperation (TC) and Nuclear Energy (NE) Departments helped Thailand solve a difficult source recovery and a long term management problem with a disused SHARS.

In February 2000, a SHARS was involved in an accident in Thailand that resulted in three deaths. Two teletherapy heads were declared as disused and were dismantled from their units. The sources were placed in a parking place awaiting collection when a scrap dealer picked them up. The heads were taken to the dealer's premises and one of them was dismantled. Not knowing the danger involved, the one source stood bare in the premises for an unknown time. It was only discovered following the clear symptoms of radiation injuries on some of the staff. The SHARS had an activity of over 1.4 TBq (400 Ci).

Following its initial recovery from the accident site, local authorities had no proper shielding or transport container needed to store the source safely. As an immediate alternative, the source was placed into a bucket and lowered into a storage pool for spent fuel rods from a research reactor. While the source was temporarily managed in the storage pool, these conditions were not ideal for the long term.

During an IAEA radium conditioning mission in Thailand, an IAEA expert was asked to review this arrangement and advise Thai authorities on better long term options. The assessment was that the source should be recovered as soon as possible and conditioned for storage.

IAEA experts devised a work plan to recover the source from the storage pool and prepared a plan to condition it once it was recovered. A self-draining shield was designed to recover the source from under water. The shield was designed to comply with both waste management and radiation protection requirements. See Figure 9-6.

Special equipment to detect any leakage from the source while it was under water was also developed. Technical procedures for the operation were developed and discussed thoroughly with the experts from Thailand who were to be involved in the recovery and conditioning operation.

The source was initially tested for leak tightness. Following confirmation that the source was not leaking, it was recovered, conditioned and rendered safe. This was the third operation where a high activity bare sealed radioactive source has been handled and conditioned with IAEA assistance. The first two operations took place in Nicaragua and Morocco. As discussed in Subsection 9.2, the IAEA is currently developing technical procedures and equipment to be able to routinely handle SHARS in countries lacking the required infrastructure and where hot cells for this purpose are not present.

original stainless steel bucket (middle) used for the initial source recovery, the long-term self drainage storage shield (left, right) designed and manufactured with IAEA assistance

Figure 9-6: Photographs of the Shield and Bucket

9.4.2 Source Recovery/Return to Supplier in Haiti

A JANUS type teletherapy machine, manufactured by Mick Radio-Nuclear Instruments Inc. (USA), was donated to the Institute Oncologique National (ION) of Haiti in 1972. Because of the simple but reliable design of JANUS machines, they continued to be installed in the late sixties and early seventies in several countries with low level infrastructures. The JANUS machine had the special feature of having two heads located in two neighbouring treatment rooms (see Figure 9-7). This feature allowed the operators to utilize the radioactive source with a higher efficiency compared to typical single-head teletherapy units.

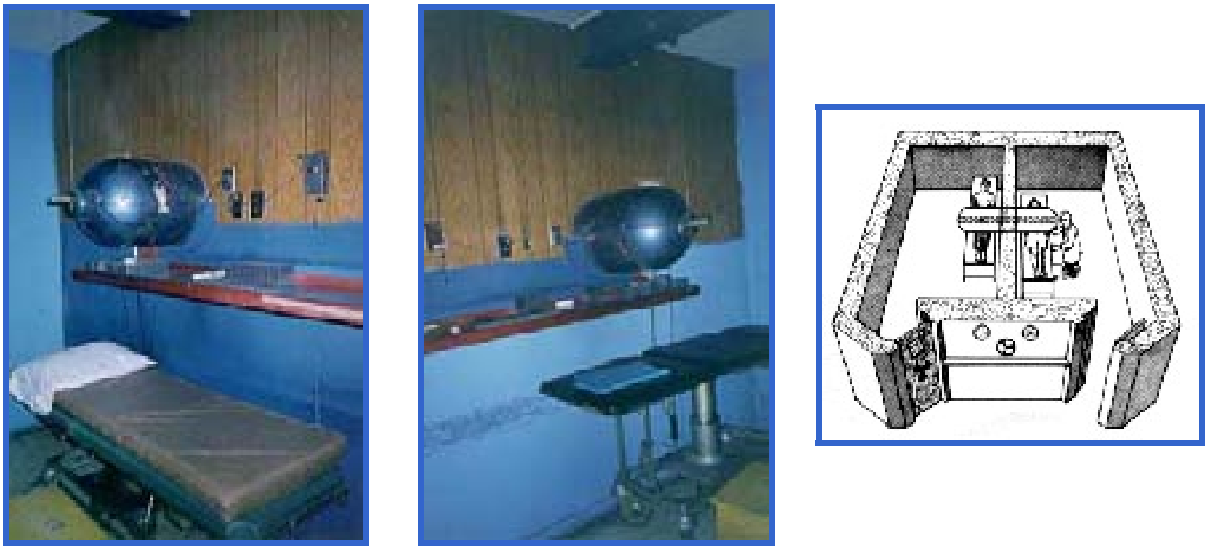

Figure 9-7: Teletherapy Treatment Facility Configuration

The last source replacement, together with equipment maintenance and calibration, took place in August of 1989. The Co-60 radioactive source was supplied by Neutron Products Inc. (USA) containing an activity of 89 TBq (1st May, 1989). Radioactive decay brought the source down to about 22 TBq and made treatment times too long to continue using the source. The ION had not accepted new patients for teletherapy since July 2000 and the machine had been out of use since January 2001. The Haitian Government asked the IAEA to put the source into a safe condition. The IAEA took immediate action and an external expert was sent to Haiti in April of 2001 to investigate the local conditions and to provide options on how to proceed further. The expert found that the source was already in a safe condition and did not pose a radiological risk to either ION staff or the environment.

The expert's report highlighted two available options to Haiti. The source could be returned to its supplier or it could be conditioned on site and stored in Haiti. Since the Haitian Government wished to investigate restarting radiotherapy treatment using its existing machine, the expert could not carry out further investigations for recovery and conditioning.

Following an almost two year break, the Haitian Government asked the IAEA for direct assistance to remove the sources from ION and from the country. In May 2003, one expert from the IAEA and another from the USA - whose company supplied the JANUS machine - carried out a preparatory mission. The most important findings of this mission were that there was a small chance of securely storing the source in Haiti and the JANUS machine contained no depleted uranium in its shielding.

Another important and unplanned achievement of the expert mission was the identification of another radioactive source. A disused, low activity Co-60 brachytherapy source was stored in the wall of the JANUS treatment room.

Procedures for the recovery operation were assembled. The first step was to clarify whether the former source supplier could perform the recovery and accept the source. Since the mission, the IAEA's Waste Technology Section (WTS) has enhanced its activities for management of high activity sources and, as a result, identified an institution to recover the sources for reuse.

The IAEA contacted Neutron Products Inc. (NPI, the source manufacturer) in mid 2003 and received valuable support (e.g. a special form certificate of the source in the JANUS machine). NPI would have been able to decommission the JANUS machine in Haiti and accept the sources but source repatriation to the US raised difficult legal and logistical questions. The option for reuse became the preferred choice.

WTS also contacted MDS Nordion for technical support to transport the JANUS source in a licensed B(U) type container. MDS Nordion generously offered the provision of a F147 B(U) type package cost free to the IAEA (see Figure 9-8).

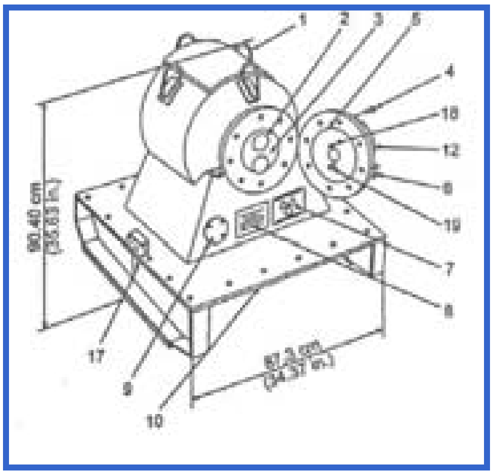

Figure 9-8: Schematic of an F147 B(U) Package

As the IAEA was in the possession of the most important documents (e.g. special form certificate) and the necessary technical support (licensed transport container), the bidding process could start in late 2003. The IAEA's Technical Co-operation Department called six companies worldwide to bid for the job. The Purchase Order was sent to the successful bidder in January 2004.

Although the operation in Haiti was scheduled for April 2004, implementation has been delayed due to the political situation. The contractor and MDS Nordion agreed on starting the operation as soon as the safety of the source container and the contractor's personnel could be assured.

9.4.3 Multiple Source Recovery in Côte d'Ivoire

A general purpose irradiator, type Lisa 3, built by CONSERVATOME, France, equipped with 8 Cs-137 sources having a total activity of 1480 TBq (40 000 Ci) was provided to Côte d'Ivoire in 1969. The irradiator has a 77 litre irradiation chamber and could deliver a dose rate of 700 Gy/hr when new.

The irradiator was installed at the University of Cocody, Abidjan, Côte d'Ivoire for irradiation of agricultural products. The irradiator was taken out of service in 1985 and declared as disused. A mission undertaken by the IAEA in 1997 recommended some measures to enhance the irradiator's security.

The matter was transferred to the WTS and a mission planned by the WTS to develop a solution was undertaken (9-12 April 2002). It was clear that little could be done within the available infrastructure. Further management of the source within Côte d'Ivoire was not possible. The residual activity in 2002 was about 690 TBq (18 700 Ci), sufficiently high to make the sources attractive for reuse.

A decision was made to transport the sources to France. Contact with Commission Energie Atomique (CEA) and the French Mission to the IAEA resulted in the agreement to take necessary steps to condition the source for transport in a suitable transport container and to ship it by sea to France. The scope of a mission was prepared by the IAEA and carried out by French experts from CEA, CisBio, and Transnucleaire.

The source could not be transported in its working shield alone and required a B(u) type container that can take the source with its working shield. A licensed CC25 container was selected.

The pre-mission main objective was to assess the irradiator status and provide technical, financial and administrative information in order to validate the transport operation. The technical arrangements and procedures along with required source documents were collected. This documentation was sent along with the CC25 certification to the "Autorité de Sûreté Nucléaire Française" (DGSNR) for licensing of the operation and obtaining the required authorization for the source importation into France.

At the same time it was also identified that a second source was in the same hall. The second source was a Chinese 185 GBq (5Ci) 241Am-Be neutron source provided by the IAEA. A number of smoke detectors equipped with 0.5 MBq (15 μCi) Am-241 sources were identified as well. The neutron source was conditioned for transport and was removed prior to the operation. The smoke detectors (50) were removed and the equipment hall was prepared for the operation.

The pre-mission revealed that the irradiator's sealed sources were in excellent condition with no leakage and very little corrosion. The surface dose rate was measured and confirmed to be normal (0.4 to 0.5 mSv/hr). The surrounding area dose rate was 0.3 mSv/hr. Smear tests confirmed no leakage or surface contamination (<0.4 Bq/cm^2).

The operation was organized in four steps:

- transportation of the CC25 container from France to Abidjan,
- conditioning of the source in a special over pack that fits the internal of the CC25 in Abidjan,
- shipment of the source to France (see Figure 9-9) and transportation to Saclay, and
- unloading and dismantling of the irradiator.

Figure 9-9: Source on a Low Bed Truck Prior to Shipment by Sea to France

(Credit: P. Bhakta/IAEA)

The cost of the operation was prepared and the required resources were secured. The Government of France provided US$ 225 000. The operation was planned to take place between March and April 2003, during the student holidays at the university. The actual recovery and shipment of the source took place in October 2003. The source was shipped to France for recycle into new smaller sources.

The special overpack was designed, manufactured and shipped along with the CC25 container to Abidjan. The equipment hall roof was dismantled. The irradiator was removed from the equipment hall where it was installed and placed into the overpack, which had special restraints to secure the source within it and fit properly into the cavity of the transport container.

While the source had decayed to about 690 TBq (18 700 Ci) at the time of removal, it remained highly dangerous. Cs-137 with a half-life of 30 years is no longer used for most irradiator applications, although it can be recycled to produce low activity and more chemically stable sources (ceramic form).

The source ranks in the highest category of radioactive sources (category I), because of its potential to cause harm if uncontrolled. It is in a radioactive powder form that, if it fell into the wrong hands, could be used to spike a dirty bomb. The premise the source was stored in was abandoned and accessible to the public and did not comply with any safety or security standards.

In addition to security concerns, the cesium source presented a health and safety hazard to a curious public. It would have presented a serious problem if someone unsuspectingly decided to dismantle it. About 10 to 15 minutes exposure to an unshielded source of 690 TBq (18 700 Ci) would kill. The operation was the first one on the international level that involved such a level of radioactivity. It successfully demonstrated international cooperation in source recovery operations.

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10 MANAGING THE CONSEQUENCES OF PAST PRACTICES

Article 12 of the Joint Convention [2.1] states:

> "*Each Contracting Party shall in due course take the appropriate steps to review:*
>
> *…the result of past practices in order to determine whether any intervention is needed for reasons of radiation protection bearing in mind that the reduction in detriment resulting from the reduction on dose should be sufficient to justify the harm and the costs, including the social costs of the intervention."*

Many IAEA Member States have increased their efforts in recent years to improve upon past practices and to remediate contaminated sites. The first Status and Trends report stated that the intent of this Section was to identify and report on well-known examples. Therefore, previous issues of this reports identified a number of specific situations, including:

- inadequate disposal sites
  - the Dounreay Shaft and Silo Remediation activities
- land contaminated with radioactive material due to accidents
  - the Chernobyl Shelter project
- abandoned and closed mining and milling sites
  - the Wismut uranium mines remediation

Also covered in previous issues of this report have been two broad-based initiatives, the USA's EPA Superfund Programme and the Russian Federation's Minatom Programme. Both of these programmes are addressing the legacy of radioactive waste from the Cold War.

Several Member States identified specific undertakings in their National Reports under the Joint Convention [2.1], as follows (the list is not exhaustive):

- The Republic of Slovenia:
  uranium mill tailings at Boršt
  uranium mine waste at Žirovski
- Switzerland
  Lucens experimental power reactor in Vaud
  watch industry (radium) sites in the canton of Jura
- Argentina
  PRAMU Project to address the uranium mining and milling legacy
- Sweden
  Ågesta Reactor
  Ranstad uranium mine

The issue of UMM residue/waste management is addressed in Section 4.1 and, as noted there, was the subject of an international workshop in Portugal in February 2004 (see Subsection 10.3).

However, while the examples given in previous issues of this Status and Trend report demonstrate that technical solutions are available and are being applied, the key issue concerns the justification, scope and objectives for applying such remedial actions at radioactively contaminated sites. This is discussed in the remainder of this Section.

10.1 Topical Issue: Remediation for Sustainability

Introduction

Often radioactively contaminated sites cannot be remediated to residual levels of contamination that are below concern and cannot be released for unrestricted use. Hence, they have to remain under some form of institutional control. Residual contamination, buried wastes, and other hazards may remain after clean-up is complete for several reasons: it may not be technically feasible, it may be uneconomic, there may not be sufficient resources available at the time, the health risks to remediation workers may be unacceptable, the remediation action would cause collateral damage to the environment, or the site may be actually a repository for low-level remediation wastes or other radioactive residues, such as mill tailings. A balance between social and economic cost on one side and level of protection on the other side has to be found by way of optimization [3.9]. With long lived radionuclides present, maintenance of institutional control is likely to be required for nearly unlimited periods of time.

In order to be able to maintain institutional control, techniques have to be developed to keep records for the site (its contamination and the remediation measures undertaken) accessible and understandable for very long time periods. It is also understood that institutional control involves a wide range of management measures (e.g. land-use planning, building regulations) that can only be implemented and maintained through what is known as a stewardship[4] programme. Institutional control typically also involves the maintenance of physical measures to prevent exposures, such as covers or liners. Examples of long term stewardship activities and technical uncertainties is given in Table 10-1.

Decisions about long term management of such sites are some of the most difficult society faces today. The decision-making often involves conflicting and competing goals, a considerable amount of uncertainty, possibly lack of agreement between stakeholders, and a significant investment of society's resources.

The ethical question

Long term stewardship is one conclusion from the strive for sustainable development as formulated by the Brundtland Commission [10.1] and in the Rio Declaration [10.2]. In essence, it was demanded that our current activities should not impair the ability of future generations to live in a way they choose. It is interesting to note that we are the first generation entertaining such ethical notions and that we are holding ourselves responsible for the detriments caused by past generations. Future generations will enjoy the accumulated benefits from all previous generations and one could argue that each generation should also carry some of the burden incurred by their predecessors. Hence, we could ask ourselves, whether we really need to find ‘permanent’ solutions, or whether we should not be able to leave some legacy to future generations that are likely to command more knowledge and capability than ours, and should be quite able to look after themselves.

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4 The term stewardship in essence refers to the mode of implementing and ensuring long term institutional control.

Table 10-1: Examples of Long Term Stewardship Activities and Technical Uncertainties

Reference [10.3]

Media potentially subject to stewardship	Possible Stewardship activities	Examples of technical uncertainties
Water: All contaminated groundwater and surface water sediments that cannot or have not been remediated to levels appropriate for unrestricted release	Verification and/or performance monitoring Use restriction, access controls (site comprehensive land use plan) Periodical review requirements Resources management to minimize potential for exposure	What is the likelihood that residual contaminants will move toward or impact a current or potential potable water resource? Are dense non-aqueous phase liquids (DNAPL's), heavy metals or long-lived radionuclides present in concentrations and/or locations different from those identified? Will treatment, containment and monitoring remain effective and adequate? Will ambient conditions change significantly enough to diminish the effectiveness of the selected remediation strategy?
Soils: All surface and subsurface soils where residual contamination remains, or where wastes remain under engineered caps.	Institutional controls to limit direct contact or food chain exposure. Maintaining engineered controls or markers. Periodical review requirements.	What is the likelihood of future containment migration, if ambient conditions change? How will changes in land use affect the barriers in place to prevent contaminant migration and potential exposure? What is the likelihood of cap failure sooner than expected? Whet is the effect of contaminant-caused degradation of remediation strategy components?
Engineered structures: All land-based disposal units with engineered controls.	Monitoring and inspections, per agreements, orders, or permits. Institutional controls, including restricted land use. Maintenance, including repairing caps. Periodical review requirements. Land and resources use planning to minimize potential for exposure.	What is the effect of containment caused degradation or remedy components? At what point in time will the remediation solution require significant repair or reconstruction? Is the monitoring system robust enough to capture remediation failure?

Objectives and outcomes of remedial actions

Decision-makers are faced with fundamental choices for the intended remedial action. They must decide whether they will (1) leave the site undisturbed, while establishing a monitoring scheme for determining the evolution of the site; (2) contain or restrict the mobility of the radioactive contaminants; or (3) remove the radioactive contaminants from the site, using an appropriate treatment scheme.

Remediation typically proceeds in an iterative fashion and end states emerge as the *de facto* result of multiple interim actions. The measurement of remediation success is still a developing science.

While, obviously, contaminant removal is a permanent solution for the site in question, any engineered solution to contain contaminants or to reduce exposures will only have a limited period of useful life. Natural forces will gradually degrade structures such as barriers or covers: our engineered solutions may well become the future contaminated sites. Stewardship and life-cycle management will have to take this into account.

Long term stewardship strategies

Public interest may call for low stewardship needs, but there may be economic constraints to achieve this. In some Member States, the current treasury rules and political domination of budgeting make it difficult to provide for the necessary long term funding security of stewardship programmes. Alternative instruments, such as trusts and bonds, have been proposed.

Stakeholder participation in development of stewardship plans is considered a key factor to success, as it has the potential to create ownership in the chosen solution.

Funding mechanism

Many countries today have adopted the "polluter pays principle", meaning that the originator of a contamination is responsible for adequate remediation measures. However, in many cases the originator has ceased to exist, or it is difficult, even impossible, to attribute a contamination to a single event. Due to the nature of such radiologically relevant contamination, the responsibility for making safe, clean-up and monitoring often rests with, or in the wider public interest, is assumed by the government.

Alternative funding can be sought in some instances, such as through the increase in market value of property following clean-up and added value by redevelopment (see also Section 5.1).

Record Keeping and Information Management

Records are an essential basis for a successful stewardship programme. However, there is no consensus as to which records are really important and how they should be preserved. Different stakeholders will have different information needs that also will change over time.

While archiving and maintenance procedures for paper records are fairly well established and time proven, electronic records are a major concern. Many systems that were once considered high technology simply no longer exist and records stored in the respective format became virtually lost. Also most electronic records are physically much more vulnerable than paper records.

The problem of technical obsolescence and rapid technological changes has been widely recognized and extensively discussed for many years, but without any agreement on how this can be resolved. Consequently, preserving data remains a major issue in a programme that must extend into the indefinite future.

In conclusion, in order to improve sustainability, a move away from technology driven, "end of the pipe" solutions towards a more integrated, life-cycle management approach can be observed in managing our legacies from the past.

10.2 Topical Issue: Softer Remediation Technologies

Dispersed low-level contamination poses a particular challenge to those charged with its remediation [10.4]. Many techniques are not efficient below certain concentration thresholds or entail more severe impacts on certain environmental compartments than the contamination itself. Even if justification for remediation might not be needed for radiation protection reasons, the public may demand it.

Reference [10.4] examines a variety of technological options for dealing with such contamination. The objective of any technology used in a remediation project is to either remove or reduce the source term or to block exposure pathways. This can be achieved in a variety of ways and needs to be tailored to the contaminants and pathways of interest. Hence, the approaches are broadly grouped into the three categories of:

'non-intervention'	'containment'	'removal'

While this conceptual grouping is useful to understand the objectives behind certain technologies, it may be noted that various technologies could be grouped into more than one category. The functionality of a certain technology may change over time or may combine, for instance, containment with removal.

The decision whether to actively remediate or not would be based on predictive modelling and a risk assessment. If there are no acute exposure pathways, the decision not to intervene may be justified. However, the effects of natural attenuation would be monitored in order to verify that the contamination behaves as predicted.

Reliance on natural processes may need to be complemented by a change in the use of the contaminated land in order to minimize exposures and uptake of radionuclides. Such change in land use may extend to (temporarily) dedicate agricultural land to forestry or may simply involve a change in crops. In coping with the widespread contamination following the Chernobyl accident, such agricultural countermeasures have found wide application in order to retain some use of the land.

There are various ways by which it can be attempted to enhance attenuation. Typically such measures intend to change controlling geochemical parameters, such as pH or redox potential, to values that would disfavour migration. Enhancing sorption binding capacities and intensities by soil additives have also been attempted.

Such measures gradually lead to more invasive measures to contain contamination. Outright containment by impermeable or low-permeability barriers and liners may encounter logistical problems for dispersed contamination cases. Apart from the fact that it would involve major civil engineering work, its effectiveness may be difficult to maintain.

Permeable reactive barriers seem to offer a viable alternative for a wide range of contaminants. Such barriers are intended to fix a contaminant *in situ* while allowing groundwater flow. The fixation mechanisms typically are sorption or precipitation, or a combination of both. Frequently, the reactants in the barrier are also meant to induce a change in the redox of the radionuclide (or heavy metal) concerned, leading to less mobile species. Various construction methods are employed, including trenching and injection curtains. A rather more novel application are ‘bio-walls’ that utilize microbial processes to affect fixation. See Figure 10-1.

It may also be possible to immobilize a contaminant *in situ*, rather than waiting for it to migrate into a reactive barrier. Technologies involve, for instance, either the injection of grouts to bind contaminants and to reduce the soil permeability, or the injection of reactants to precipitate the radionuclides. In the latter case, the reactant may be also compressed air or another oxidant to oxidize the iron in the groundwater to ferric oxihydroxides that act as a sorption substrate. Compared to reactive barriers, however, the amount of civil engineering work is likely to be higher.

In certain environments the dispersal of surface contamination in form of contaminated dust may be of concern. Organic polymers and other binders have been successfully used to suppress dust generation. Reducing the erodibility may also be an important first step to establish a stable vegetation cover. In addition to mechanically stabilizing the topsoil, phytostabilization can establish a well determined cycling of radionuclides in a limited eco-system, thus preventing their further dispersal.

Plants systems, and more specifically aqueous plant systems, are actively used to sequester radionuclides from surface waters, including mine drainage and drainage from waste disposal facilities. While such (constructed) wetlands have a certain attraction in requiring relatively little attendance, once established, the longevity of the solution very much depends on the stability of the eco-system created. When, for instance, a wetland dries out, there is the risk of the radionuclides trapped in the root-system or the shoots to become re-mobilized. In climates with severe winters, such constructed wetlands may only function during the summer vegetation period.

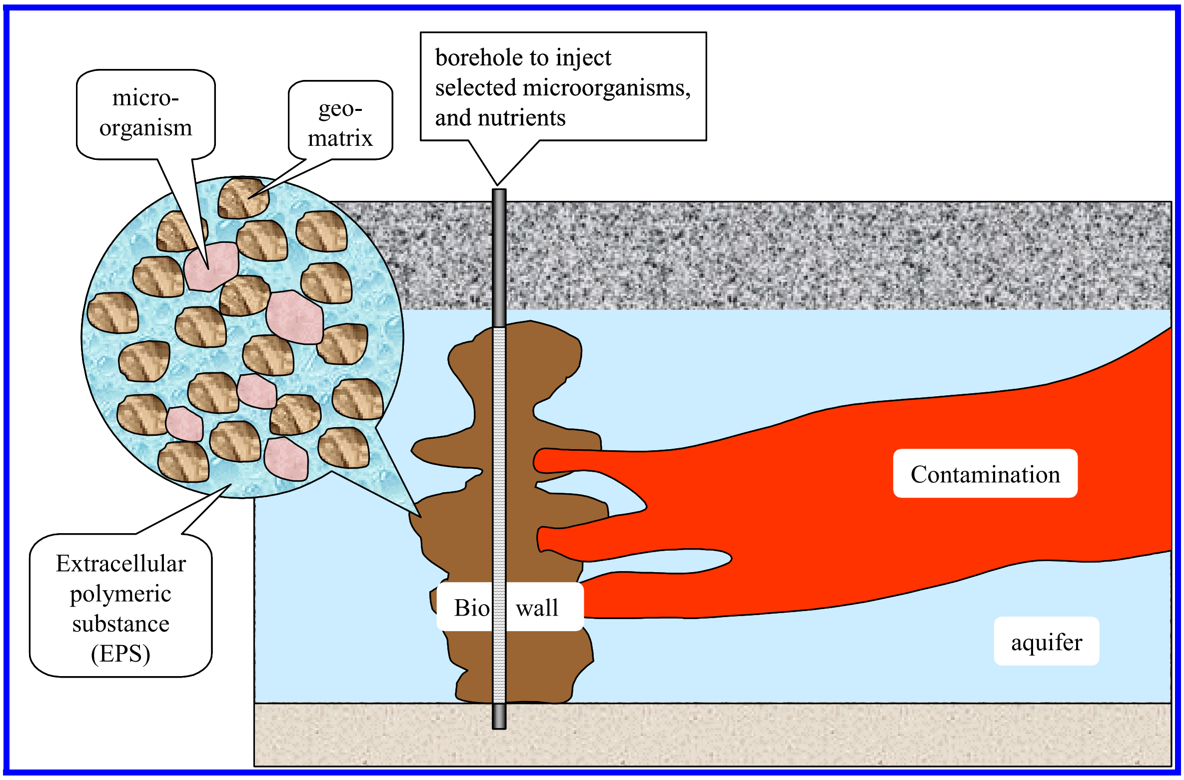

Figure 10-1: The Principle of a 'bio-wall'

The baseline techniques for contamination removal from soils and groundwater are excavation and pump-and-treat respectively. While excavation removes the contamination – if carried out judiciously – it creates equivalent volumes of material that must be treated and disposed. In the case of dispersed contamination, this may potentially lead to large volumes of waste and hence may not be feasible. The excavated material also may have to be replaced with other uncontaminated material for which no resource may be available.

Pump-and-treat methods are based on the assumption that the source can be completely removed by physical displacement. Experience and predictive modelling of the controlling processes have, however, shown that almost always a residual contamination will remain. This residual contamination will manifest itself as a long concentration 'tail' under a steady pumping regime and may result in rising concentrations when pumping is stopped or interrupted. For this reason, nowadays pump-and-treat is considered more a (dynamic) containment technique than a real removal technique.

This probably applies even if enhanced recovery techniques are applied, such as injecting lixiviants into an aquifer. Likely recovery rates can be estimated taking into account the experience of the oil industry and the mining industry employing *in situ* leaching (ISL). More than half of the original concentrations of the target material (oil, metal value) may remain underground. Leaching techniques have also been applied to the vadose zone, but little information exists on their efficiency for the removal of non-biodegradable materials.

If applied *ex situ*, extraction techniques will be able to overcome hydrodynamic limitations by agitating the excavated material as a slurry etc. Arrangements such as heap leaching have the advantage that the soil or rock structure can be broken down and thus the limitations due to heterogeneities can be overcome. This may not hold, however, at the microscopic level. Fine-grained material may need to be disintegrated considerably to achieve reasonable recovery rates.

Heap leaching, like various other leaching methods may involve a (micro-)biological component. Bio-leaching can be actively promoted by stimulating the growth of specialized microorganisms. These microorganisms influence their geochemical environment and may involve the radionuclides in their metabolic activity, which leads to a mobilization of the radionuclides. The main advantage of bio-leaching is seen in obviating the use of large quantities of lixiviants, such as strong acids, and the ensuing need to dispose of these lixiviants once the remediation is completed.

The efficiency of any *ex situ* removal process can be significantly enhanced by appropriate characterization and preceding segregation of contaminated materials. Inorganic and organic contaminations tend to be preferentially associated with the fine fraction of soils and, hence, a grain-size separation will greatly reduce the amount of material requiring treatment.

It is important to note that any extractive technique when applied to a topsoil is likely to seriously impair its functionality and fertility, resulting in a sterile material.

Over the last few decades, many processes for removing radionuclides and other metals from solutions have been developed. In addition to the 'traditional' precipitation, sorption, and ionic exchange methods various biotechnology methods, such as bio-sorption, have been developed. Although data on large scale application in a remediation context are still lacking, the experience gained from metallurgical applications is promising.

Higher plants can also be used to extract metals, including radionuclides, from soil. The uptake is very plant and radionuclide specific. After the Chernobyl accident, plant uptake by various agricultural species was extensively studied, both with a view to identify minimal uptake conditions and to maximize uptake in a phytoextraction context. The data showed that the rate of sequestration would be 1-2% of the total soil reservoir at best per crop cycle, resulting in proportionate long treatment times. Addition of complexing agents to the soil can help mobilize radionuclides, such as uranium, and facilitate plant uptake, resulting in sequestration rates of up to 5%. The potentially negative effect of such additives on plant growth and biomass yield, however, has to be carefully evaluated. The effective depth of phytoextraction is limited by the penetration depth of the roots, which is typically the tilling depth on agricultural soils. Adequate uses or disposal routes for the harvested contaminated biomass have to be found.

Another technique involving higher plants to sequester radionuclides from solution is rhizofiltration. Here, the geochemical environment created by plant roots is utilized to remove radionuclides from solutions. A variety of physico-chemical processes may actually be at work. Radionuclides that are less mobile under reducing conditions, such as uranium, and that sorb more readily, are more accessible to fixation by rhizofiltration than radionuclides that belong to the alkaline or earth-alkaline groups (Cs and Sr).

This review shows that a wide variety of remediation technologies have been developed over the years. Dealing with dispersed radionuclides in the topsoil, however, remains difficult. There are serious trade-offs to be made between the degree of invasiveness and the efficiency of a technique. The sheer volume of material to be treated often precludes the use of certain techniques that are known to be efficient. Where direct exposure is not a concern, techniques and strategies that prevent further dispersion and, hence, limit or interrupt pathways by which the radionuclides would enter the food pathway seem to be the most appropriate.

Similarly, removal of radionuclides from groundwaters tends to be rather inefficient. Containment to prevent further dispersal, for instance by reactive barriers, appears to be a better choice.

In all cases, where direct exposure is not a concern, monitored natural attenuation would be the baseline, against which active remediation measures would be evaluated.

10.3 Topical Issue: Remediation of the Small Scale Uranium Mining Legacy in South Western Europe

Environmental impact and remediation/rehabilitation of abandoned uranium mine sites, after a long radioactive-ore mining period (1907-2001) is one of the main environmental issues in Portugal, as well as other IAEA Member States in south western Europe, and was the subject of an international workshop co-organized by the IAEA and ITN Portugal in February 2004 [4.3].

Mining of radioactive ores in Portugal took place at about 56 sites, initially for radium and later for uranium. As a result, there are about 3 million tonnes of radioactive mining residues. A preliminary assessment of the radioactivity in the areas of open pit mines and milling tailings has been made, thus enabling areas of higher dose and environmental impact to be identified.

Since many of the mines were located in regions with relatively high population density, radioactivity in public water supplies and radon exhalation rates are important areas for study.

In planning the remediation strategy for the mines, extensive use is being made of experience elsewhere in establishing a management strategy the need to balance the reduction of risk and the expenditure of resources. It is however accepted that in many cases, such sites cannot be remediated to residual levels of contamination and therefore cannot be released for unrestricted use. Hence the need for "stewardship" arises to allow for the maintenance of institutional control over such areas for many years.

References for Section 10

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10.2 United Nations, Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992, vol. I, Resolutions adopted by the Conference, United Nations publication, Sales No. E.93I.8 (1992)

10.3 Krause et al., "The Mound long-term stewardship initiative", Proceedings of Waste Management WM'02, February 24-28, 2002, Tucson, paper 91AZ, USA (2002).

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11 DATA COLLECTION AND REPORTING

The IAEA attaches a high importance to the dissemination of information that can assist Member States with the development, implementation, maintenance and continuous improvement of systems, programmes and activities that support the nuclear fuel cycle and nuclear applications. The main purpose of this Status and Trends report is to support the IAEA's strategy. This fourth issue of the report represents the continuation of a process to improve the reporting of status and trends in radioactive waste management.

The structure of this Status and Trends report was derived with the intent of developing a formal framework for the assembly of information in radioactive waste management. The objectives were:

1. to identify subject areas deemed to be of interest to Member States and the IAEA,
2. to report the status of and trends in radioactive waste management according to these subject areas, and
3. to base this reporting, to the greatest extent practicable, on quantitative data.

Objectives 1 and 2 were achieved with the first issue of this report. However, currently, quantitative data are not available at a sufficient level to achieve objective 3. This issue is addressed within this Section of the Status and Trends report.

The first three issues of this Status and Trends report described the IAEA's activities to collect and disseminate information about national radioactive waste management programmes and waste inventories at the international level in the context of:

- harmonization of information collection and reporting by various international organizations, such as the IAEA, the European Commission and the Nuclear Energy Agency of the Organization of Economic Cooperation and Development (see Figure 3-1 in this issue);
- support for and consistency with the information in National Reports of the Contracting Parties to the Joint Convention (see Section 2 in this issue);
- fostering improved understanding of national programmes and inventories by comparing nationally based waste classification schemes with the IAEA's proposed common classification scheme (see Section 3 in this issue) and by implementing a scorecard for the implementation of national systems for radioactive waste management (see Table 2-1 and Table 2-2 in this issue);
- providing guidance for record keeping and record management at the national level (see Subsections 5.4 and 11.3 in this issue);
- supporting the Indicator of Sustainable Development for Radioactive Waste Management [11.1], the compilation of a comprehensive, international radioactive waste inventory based upon a common classification scheme [11.2], and support for the routine reporting of the status of and trends in the field of radioactive waste management; and
- implementing publicly accessible information systems about radioactive waste and its management (see next).

In the current issue, updates of three subject areas covered in the previous issue of this report are presented, namely:

- update on NEWMDB Data Collection and Reporting (Subsection 11.1),
- update on the Directory of Radioactively Contaminated Sites (Subsection 11.2), and

- update on Guidance for Record Keeping and Records Management (Subsection 11.3).

In addition, a new Topical Issue discusses the IAEA's Waste Management Research Abstracts (WMRA) database (Subsection 11.4).

11.1 Update - NEWMDB Data Collection and Reporting

As indicated in Subsection 6.3.2, IAEA Member State participation in the first two data collection cycle was low – only 36 submissions were received. However, the participating Member States had 70% of the operating nuclear power plants world wide and, therefore, the inventories they reported represent most of the world's radioactive waste (within the scope of the data collection). An intensive review of NEWMDB use and a compilation of lessons learned were conducted by way of an IAEA consultants' meeting (March 2002), three international workshops funded by the Government of Japan (October 2002, November 2002 and January 2003) and a May 2003 workshop attended by experts from seven Member States. Work commenced on the development of NEWMDB version II in June 2003.

NEWMDB-II was made available to Country Coordinators for the NEWMDB in January 2004. Country Coordinators are appointed by their Governments to act as a single point of contact with the NEWMDB Programme Officer. The third ("2003") data collection cycle was conducted March to July 2004 – instructions for accessing the information collected are accessible via the following Internet link:

http://www-newmdb.iaea.org/help/instructions2003.pdf

The principal goals for developing NEWMDB version II were to:

- greatly improve its ease of use (to promote an increase in its usage),
- enhance its documentation (to make it more understandable to both Authorized and Public Users), and
- minimize changes to the scope and nature of the data collected (to minimize the burden on submitting data to the database).

Regarding the last bullet above, some changes to the scope and nature of data collected were unavoidable - they reflect a consensus view of changes requested during the review process described above. On a Member State-by-Member State basis, the IAEA migrated data collected during the first data collection cycles into new "2003 submissions". In addition, the IAEA provided "maps" to the relevant CCs that described how the data for their countries were migrated. The purpose of the migration was to reuse as much of the data from previous submissions as possible so that CCs would only have to update information that had changed since their country's previous submission (to minimize the reporting burden).

Regarding the second bullet above, a detailed "submission flowchart" was developed to provide step-by-step guidance for submitting data to the database. Additionally, the flowchart was translated into all IAEA Official Languages (Arabic, Chinese, French, Spanish and Russian). All versions of the flowchart can be accessed via the NEWMDB's home page [2.3]. While the main purpose of the flowchart is to help Authorized Users make submissions to the database, it is also a valuable source of information for Public Users to learn about the scope and nature of data collected using the NEWMDB.

Figure 11-1 shows how Member States define facilities that store wastes (facilities for processing and disposal can also be defined). Shown in the figure are the data migrated from Japan's previous submission to the NEWMDB. The data fields "Capacity", "Year Opened", "Closed?" and "List SRS?" are new to NEWMDB-II and, therefore, had to be completed during the "2003" submission cycle. The

"Waste Class" and "Full?" data fields are also new but the "Actual" and "Full?" fields were "populated" based on information reported previously.

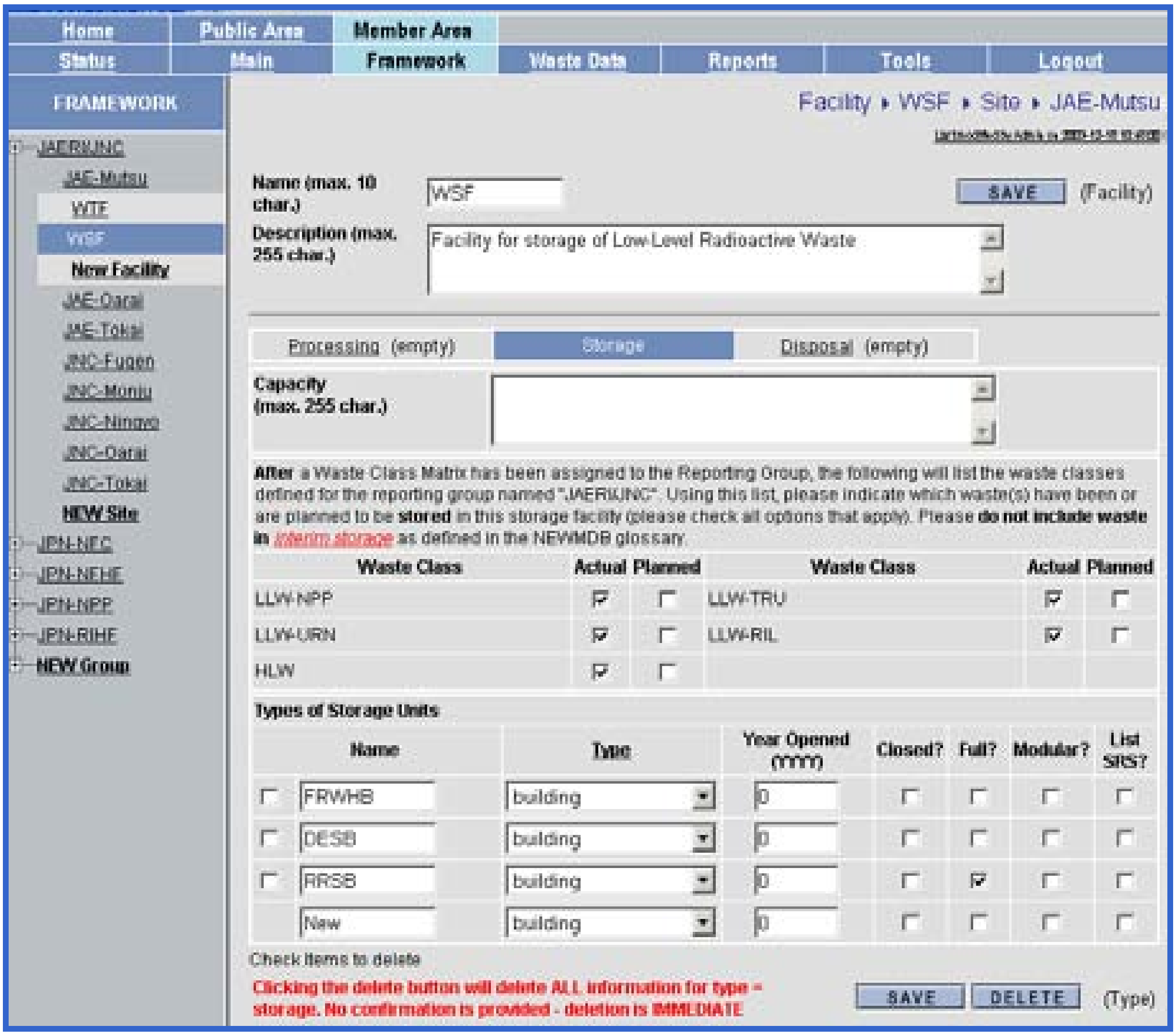

Figure 11-1: Example Screen for Defining Waste Management Facilities at a Waste Management Site

Figure 11-2 shows a typical data entry screen for Member States to indicate the amount of waste at a waste management site. Inventories are reported according to waste class (as indicated when the reporting structure was defined, see Figure 11-1), by disposition (storage and/or disposal), by processing status (unprocessed and/or processed), and by origin (Reactor Operation waste, Fuel Fabrication waste, etc.). Since the distribution by origin is not always fully known (e.g., for historic waste), a new data field "not determined" was added in NEWMDB-II. Additionally, an "estimated" field was added to cover cases where a distribution is not known with certainty. These new data fields had to be completed during the "2003" submission cycle.

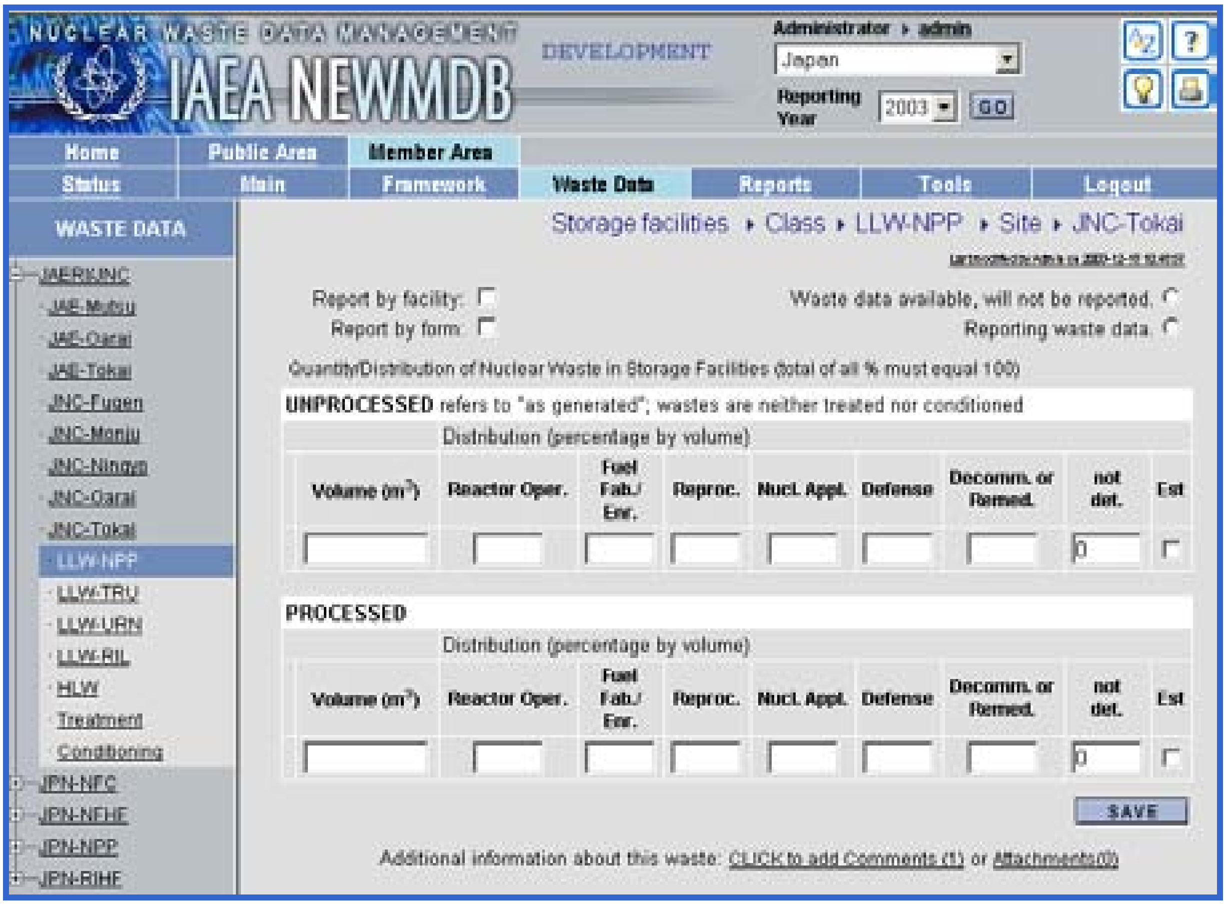

Figure 11-2: Example Waste Inventory Data Entry Screen

In the original NEWMDB, Member States specified the total inventory of each class of radioactive waste at each waste management Site. In NEWMDB-II, Authorized Users have been given the option to report waste inventories in each facility at a Site and/or to separately report inventories of liquid and solid wastes. Figure 11-3 illustrates the effect of checking the “Report by facility” and “Report by form” boxes shown in Figure 11-2, followed by clicking the SAVE button.

Figure 11-2 and Figure 11-3 illustrate the flexibility of reporting to NEWMDB-II. If a Member State wants to report waste inventories facility-by-facility or liquid and solid waste inventories separately at a Site, it can choose to do so. This freedom to choose does not impact upon those Member States that want to report the entire inventory at a Site.

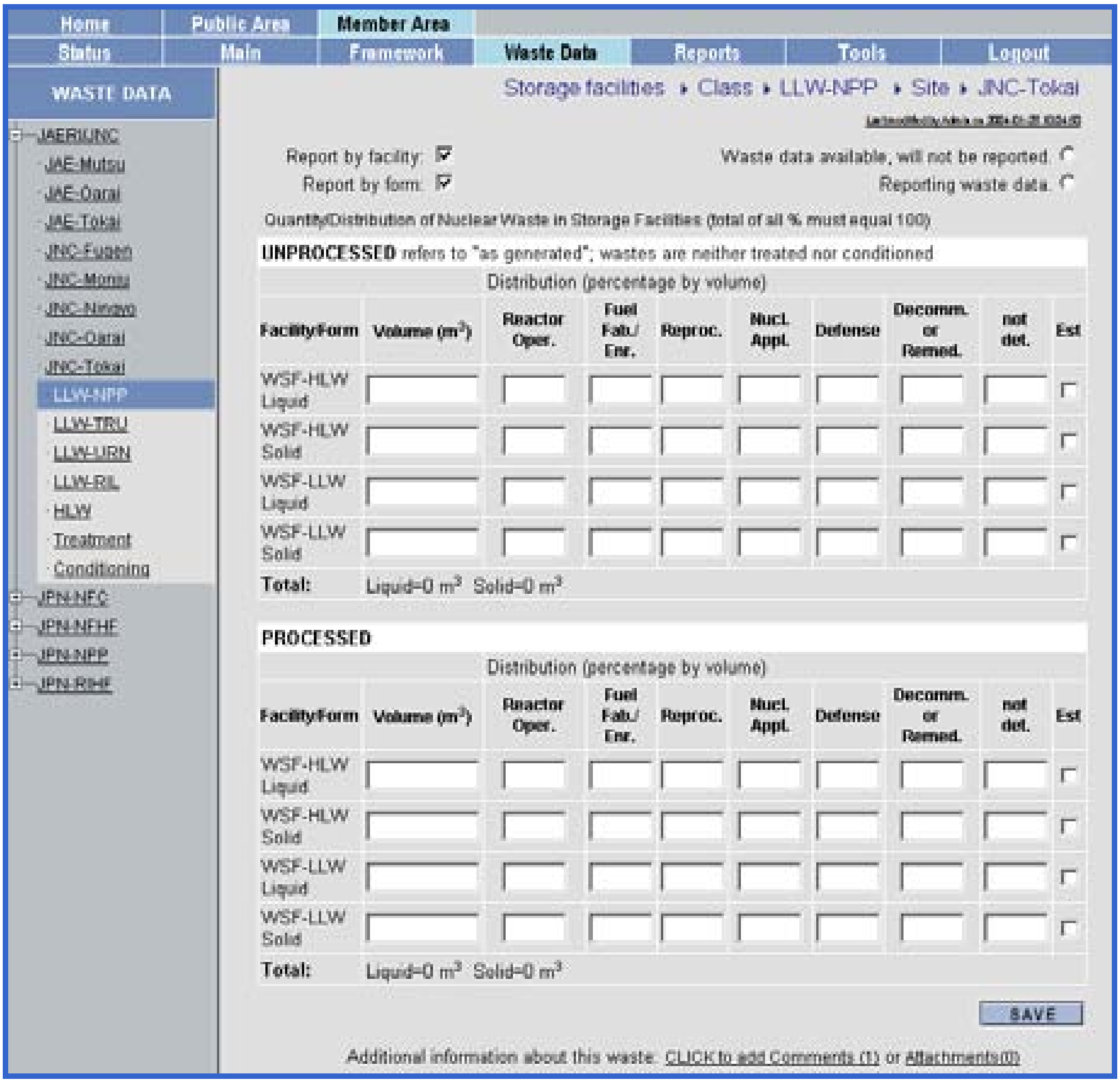

Figure 11-3: Example Waste Inventory Data Entry Screen: Reporting by Facility and Liquid/Solid Form

11.2 Update - The Directory of Radioactively Contaminated Sites

A key instrument for collecting and disseminating information about radioactively contaminated sites and pertinent management strategies and remediation techniques is the Directory of Radioactively Contaminated Sites (DRCS), which was developed by the IAEA.

The DRCS is divided into two domains, one public, the other one private. The public domain allows the free viewing of the published database content. The private domain serves to submit data to DRCS.

The data are grouped into 18 main categories, ranging from site identifiers, to geographical, geological, hydrological, socio-economic data and characteristics of the contaminants, hazards and impacts, remediation measures, to references to pertinent published references (Figure 11-4).

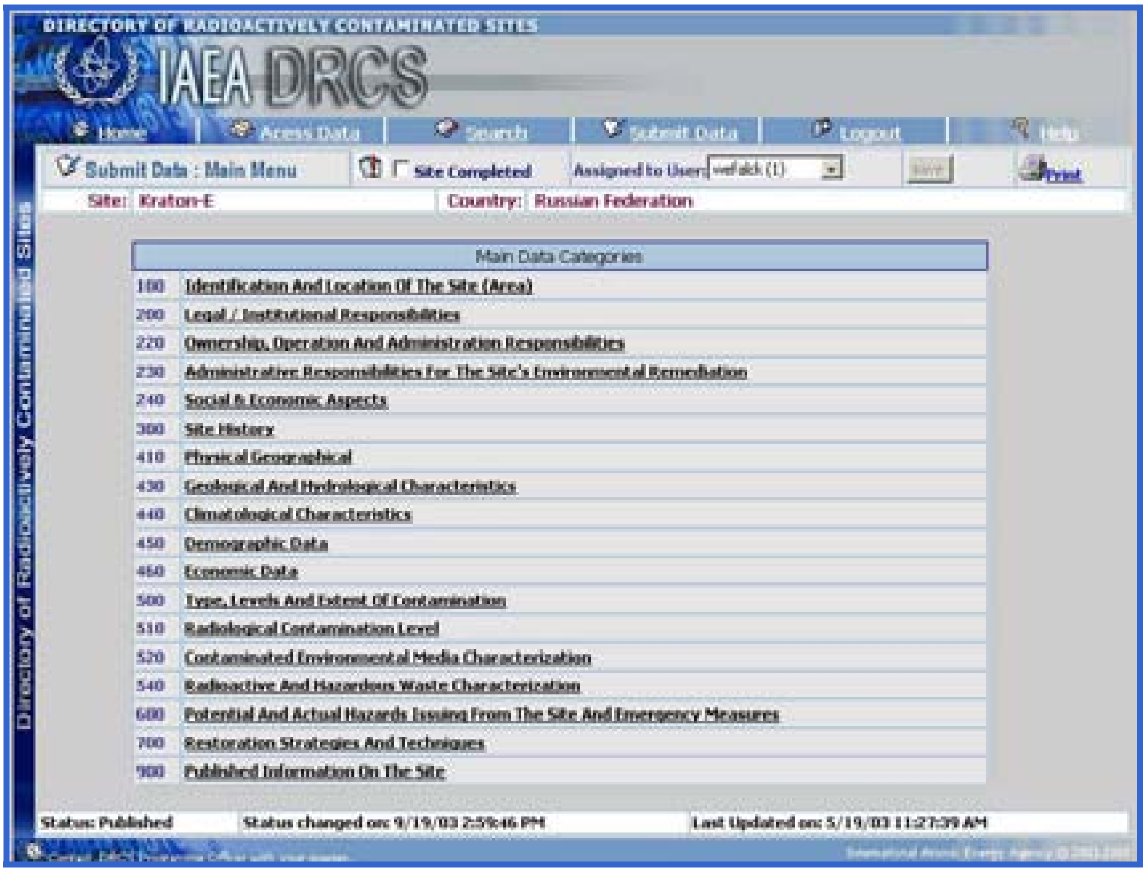

Figure 11-4: Main Data Categories in the DRCS

Sites of interest can by selected by two routes of entry:

- a sequence of 'clickable' maps is provided, 'drilling down' from the World, to regions, to individual Member States. On this last level, 'hot spots' identify individual sites that then can be clicked (Figure 11-5).
- a list of Member States (MS) and a list of sites within the boundaries of this MS is provided from which to choose (Figure 11-6 and Figure 11-7).

While Figure 11-6 and Figure 11-7 show examples of 'data entry' pages, the 'view only' pages look very much the same, except that, of course, nothing can be changed. The user can view the pages in sequences using a 'next' button, or navigate through the site information using the main selection page. Users can create search profiles that provide a list of sites matching the selection criteria.

The main tool for data collection is a system of Country Contact Points (CCPs) that has been established in the Member States. To date, 26 countries have registered CCPs. These CCPs will collate relevant site data and ensure that they are compatible with the respective Member State's policy and information practices. This route was chosen in order to avoid possible conflicts over the decision what constitutes a 'contaminated site'. The definition may vary from Member State to Member State and the IAEA does not want to prejudice a decision in a Member State.

The DRCS is now operational and accessible via the Internet [11.3]. However, the data content at present is very limited, pending submissions by the CCPs. The IAEA invites contributions to this ongoing programme. The contact details for the relevant CCP can be obtained from the DRCS administrator (DRCSProgrammeOfficer@iaea.org).

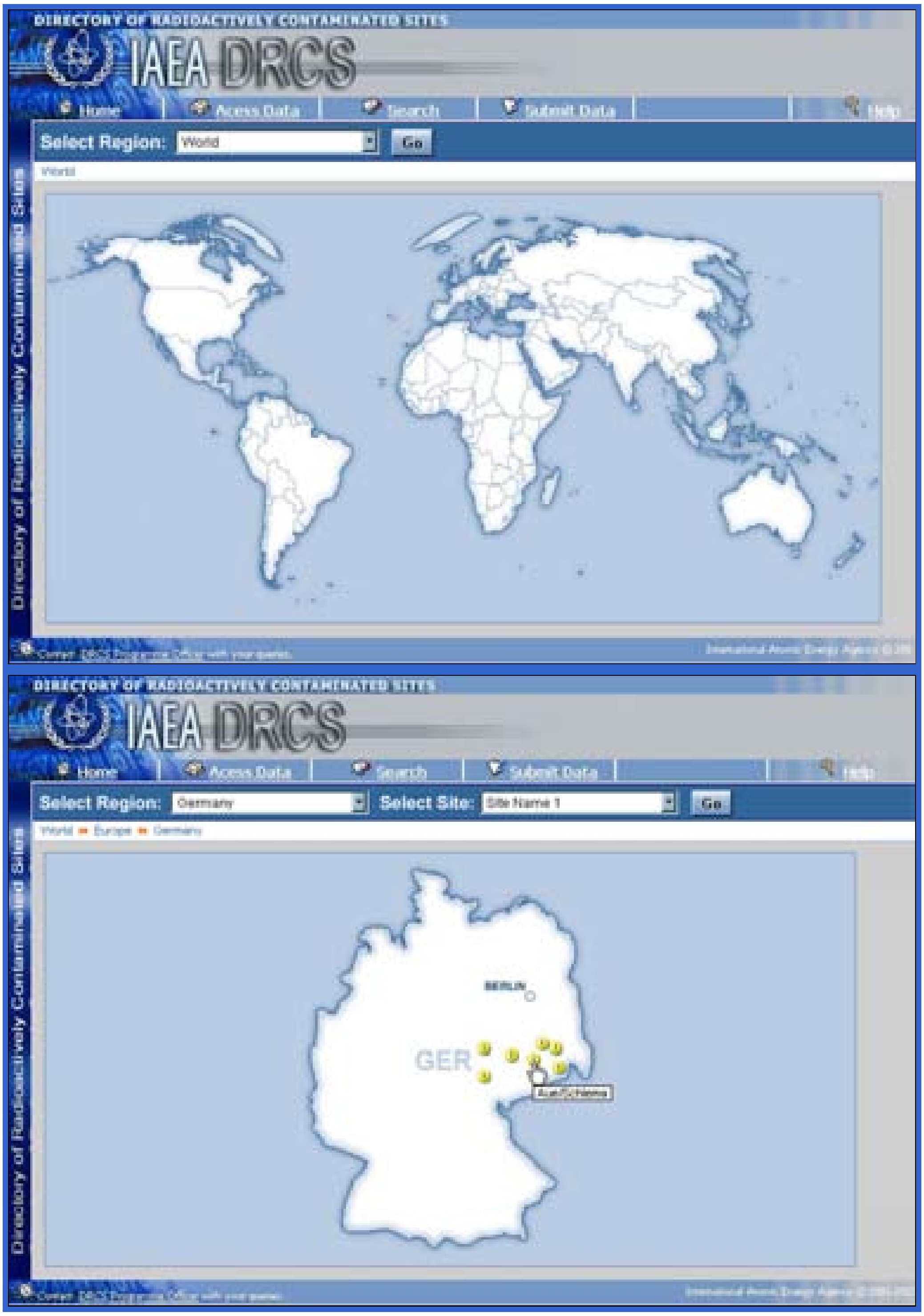

Figure 11-5: Contaminated site selection by 'clickable' maps (dummy page)

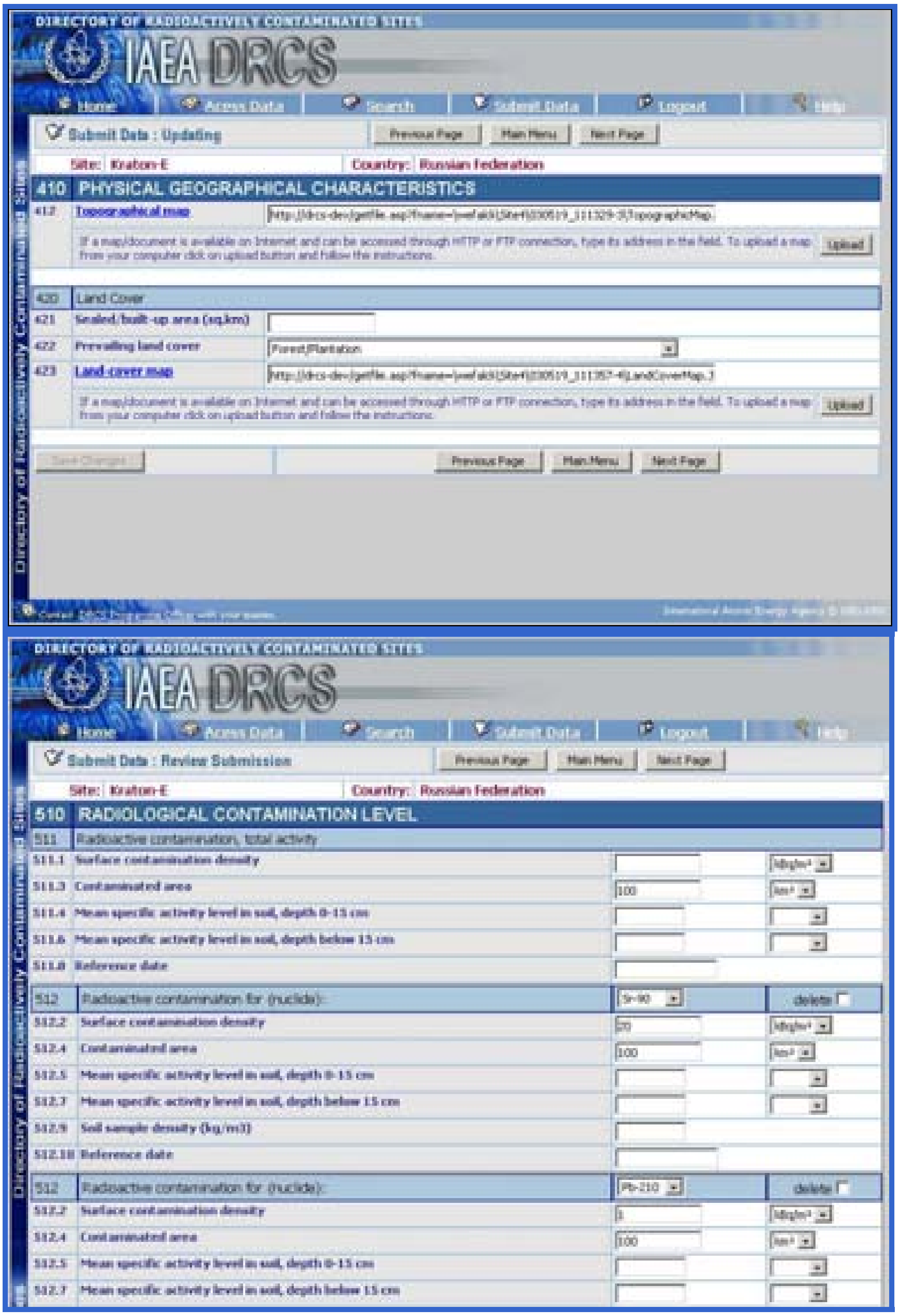

Figure 11-6: Sample Data Entry Pages – Geographical Characteristics and Radiological Contamination Level

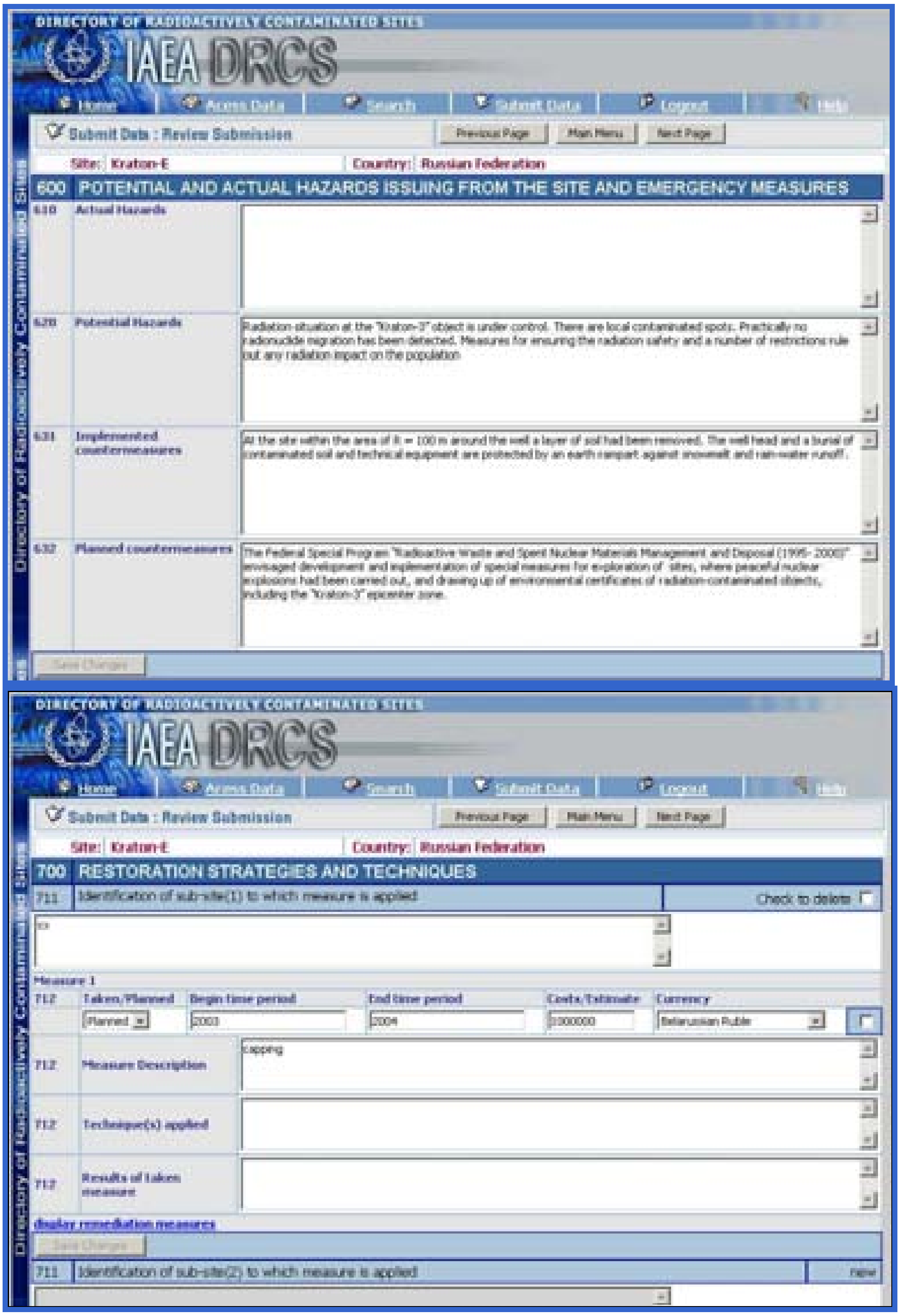

Figure 11-7: Sample Data Entry Pages – Detailed Information on Site Hazards and Remediation Measures

11.3 Update - Guidance for Record Keeping and Record Management

Section 11.2 in previous issues of this Status and Trends report identified IAEA initiatives to address the harmonization and sharing of waste management information at both the national and international levels. The following provides and update of those initiatives. In addition, please see Subsection 5.4, "Record Keeping for Decommissioning".

Radioactive Waste Management Registry (RWM Registry)

The RWM Registry deals with solid, liquid waste and sealed sources (SRS) that are generated on a routine or non-routine basis and covers waste processing steps. The RWM Registry is also able to track the history of waste records. The quality control of final waste product and the quality assurance program of waste processing are addressed as the optional entries. Additionally, the RWM Registry records information on status of the waste.

The RWM Registry is structured to allow a high degree of flexibility. There is a set of customized tables that are prepared by users according to their requirements and needs. Formation of the RWM Registry takes into account different sizes and complexity of waste management organizations in different countries.

The RWM Registry is also a managerial tool and offers an immediate overview of the various waste management steps and needs. This would facilitate planning, optimizing resources, monitoring of related data, disseminating of information, taking actions and making decisions.

Outputs from the RWM Registry can form part of a national waste management report, as requested by the regulatory body, by the Joint Convention [2.1] or by the NEWMDB. The RWM Registry is designed primarily to assist Member States with waste generated from nuclear applications, however in it could be also used for keeping inventory for waste generated from nuclear power plants and nuclear industries.

The second release of the RWM registry has been completed and available since October 2003. A user manual has also been produced as working material. The terms of distribution are being reviewed and a mechanism to provide the required training for proper, efficient and easy use of the software is being considered. The RWM Registry has been delivered to 20 Member States as of the end of 2004.

To obtain information on the RWM Registry, please contact the IAEA via email using the address RWMR@iaea.org.

"Primary Level Information (PLI) Set" TECDOC: The "PLI" TECDOC was developed and published in 2004 [6.3] as a follow up to two TECDOCs published previously by the IAEA:

"Maintenance of Records for Radioactive Waste Disposal", IAEA-TECDOC-1097, July 1999.

"Waste Inventory Record Keeping Systems (WIRKS) for the Management and Disposal of Radioactive Waste", IAEA-TECDOC-1222, June 2001.

Briefly, the previous TECDOCs described hierarchical record management systems consisting of primary level information (PLI), intermediate level information (ILI) and high level information (HLI).

TECDOC 1097 states "*...This report discusses information gathering and maintenance of records. It does not give advice on specific details of what these records will cover which may be governed by applicable national regulations...*"

TECDOC 1222, states "*...pre-closure records comprise the PLI set… … A WIRKS represents a subset of the PLI… …While this report provides technical advice about the*

> *development and implementation of a WIRKS, it does not cover any other aspects of the PLI, which could be the area where most Member State data are compiled and which represents a significant cost to those Member States with large nuclear programmes. The participants at the third Consultants meeting recommended that technical advice on the development and implementation of a comprehensive PLI should be provided…*". The PLI TECDOC was developed to meet the cited recommendation.

In support of its initiatives to harmonize information at the national and international levels, the IAEA recently updated and re-issued its Radioactive Waste Management Glossary (WMG) [4.12], which had not been updated since 1993. Experience gained during the first two data collection cycles with the NEWMDB and its predecessor, the Waste Management Database, highlighted the need to complete the WMG. As an example, during the preparation of their submissions to the NEWMDB, Member States used terms such as “interim storage”, “short term storage”, “temporary storage”, “interim temporary storage”, and even “long term interim storage”. The NEWMDB Programme Officer strongly discouraged such terminology, citing the IAEA’s definition of storage, which follows:

> **storage.** The holding of spent fuel or of radioactive waste in a facility that provides for its containment, with the intention of retrieval [4.12]. Storage is by definition an *interim* measure, and the term *interim storage* would therefore be appropriate only to refer to short term temporary storage when contrasting this with the longer term fate of the waste. Storage as defined above should not be described as interim storage.

The consistent use of terminology is essential to ensure consistent reporting of information at both the national and international levels. As an example, the NEWMDB’s On Line Help states the following:

> To avoid possible double accounting, waste that is in storage awaiting transfer to an available disposition option is excluded from the scope of the NEWMDB. Examples are hospitals, universities and research centres carrying out what is often referred to as **interim storage** prior to transfer of the waste to a central, licensed waste management facility (processing, storage or disposal). Waste that is being held because there is no disposition option would be included in the NEWMDB. For example, when this Help file was written, "greater than class C" waste was being held at reactor sites in the USA because a repository for this waste was unavailable. The waste at the reactors would be reportable to the NEWMDB.

To ensure consistent reporting of waste to the NEWMDB, it is essential that participants use the same definitions to describe their waste management programmes and inventories. The WMG is instrumental in achieving this objective.

11.4 Topical Issue: The Waste Management Research Abstracts (WMRA) Database

The Waste Management Research Abstracts (WMRA) is a collection of research summaries, planned or in progress, in the field of radioactive waste - including activities related to the decommissioning of nuclear facilities and environmental restoration.

Collection of research abstracts started in the late 1960s and have continued since. There are currently 23 printed volumes of the WMRA. In 1997, with the introduction of the International Research Abstract Information System, abstracts are submitted by researchers on-line, which enables immediate access and retrieval via the Internet [11.4]. The 28th volume of abstracts was published November 2003 [11.5]. CD ROM copies can be ordered via the WMRA web site (see Reference [11.4]).

The total number of abstracts published in WMRA 28 is 184, which breaks an annual decline in the number of abstracts that has occurred over the last several volumes (see Figure 11-8). In addition, a lower percentage of abstracts derived from the United States of America (i.e., WMRA 28 has a higher percentage of individual abstract submissions from countries other than the USA).

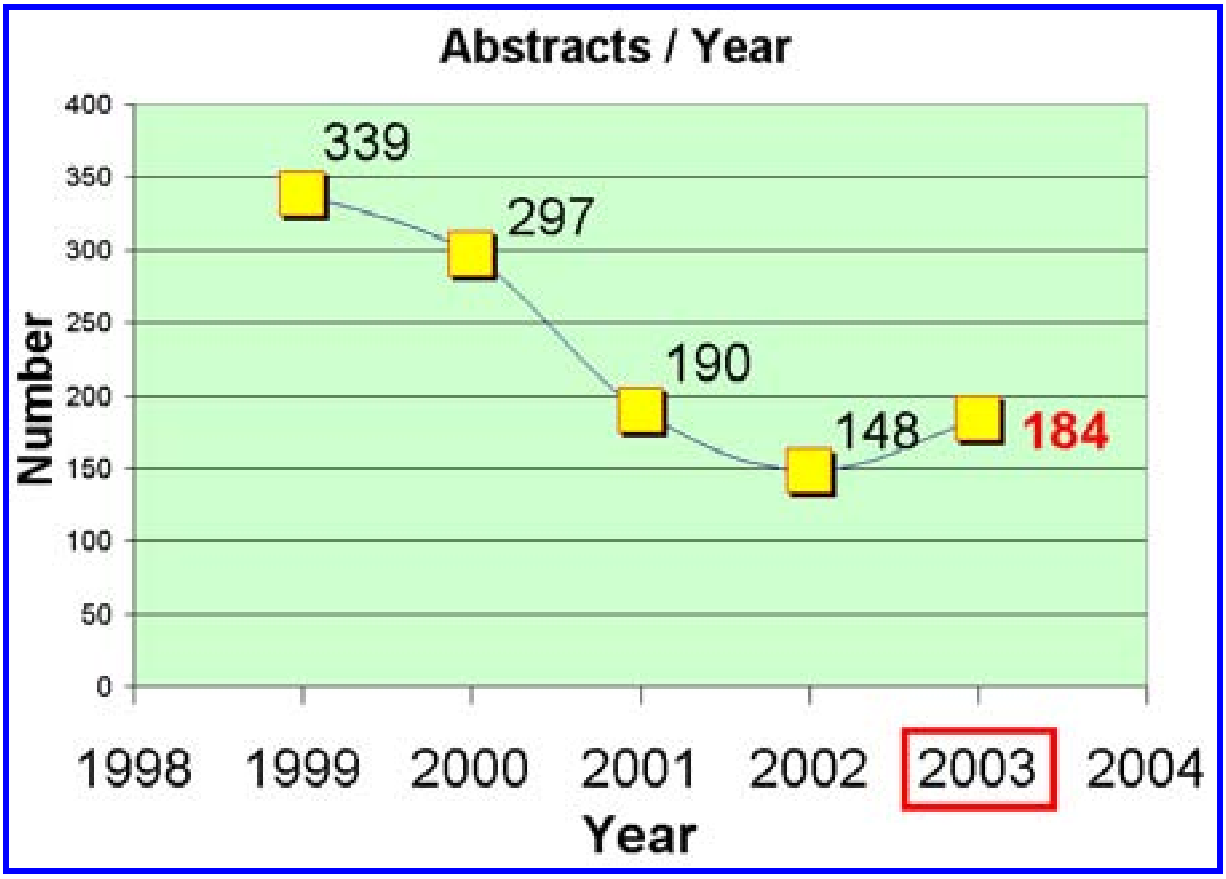

Figure 11-8:Number of Research Abstracts Submitted Per Year

Previous declines in abstract submissions may be due to decreased international interest in the WMRA, perhaps related to the variety of information sources on the Internet. It may also be due to decreases in waste management related research being conducted in Member States. The IAEA will continue to seek abstract submissions (a request for abstracts to WMRA volume 29 was issued April 2004) but it will also assess whether or not to continue offering this service if interest continues to fall (was the increase in abstracts in 2003 an anomaly?).

References for Section 11

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http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/isd-ms2001economicB.htm#radioactivewaste

11.2 International Atomic Energy Agency, “Radioactive Waste Management Profiles a Compilation of Data from the Net Enabled Waste Management Database (NEWMDB) No. 5”, sub-report “OVERVIEW REPORT: Consolidated Radioactive Waste Inventory”, CD ROM IAEA/WMDB/5, Vienna, (2003).
http://www-pub.iaea.org/MTCD/publications/PDF/rwmp-5/INV.pdf

11.3 home page for the Directory of Radioactively Contaminated Sites
http://www-drcs.iaea.org/

11.4 home page for the Waste Management Research Abstracts
http://www.iaea.org/cgi-bin/irais.showwmt.pl?wmwmra.wmt

11.5 International Atomic Energy Agency, “Waste Management Research Abstracts – Information on Radioactive Waste Management Research in Progress or Planned”, CD ROM IAEA/WMRA/28, Vienna, (2003).
http://www-pub.iaea.org/MTCD/publications/PDF/wmra-28/WMRA28.pdf

12 HIGHLIGHTS OF THE WORK OF THE IAEA AND OTHER INTERNATIONAL ORGANIZATIONS IN 2003

The purpose of this Section of the Status and Trends report is to provide an overview of recent activities carried out by the IAEA and other international organizations in areas related to radioactive waste management. Subsections include overviews of recent activities of the European Commission (EC, Subsection 12.3), the Nuclear Energy Agency of the Organization of Economic Cooperation and Development (OECD/NEA, Subsection 12.4), the International Commission on Radiological Protection (ICRP, Subsection 12.5) and the International Association for the Environmentally Safe Disposal of Radioactive Material (EDRAM, Subsection 12.6)

12.1 Highlights of the IAEA

12.1.1 International Radioactive Waste Technical Committee (WATEC)

The International Radioactive Waste Technical Committee (WATEC) was established in 2001 as an international forum for reviewing developments and providing advice to the IAEA on technical aspects of radioactive waste and materials management, for exchanging information on the status of and trends in national radioactive waste management programmes, and for providing the Secretariat with up-to-date information on technology development, Member State experience and arising issues in radioactive waste management.

WATEC held its third meeting in September/October 2003 at the Agency Headquarters in Vienna. Eighteen waste management experts, representing 14 Member States and the OECD/NEA, participated in the meeting. Mr. R. Holmes of BNFL (UK) chaired the meeting.

With respect to predisposal waste management, WATEC recognized a growing tendency in Member States to use long term storage of waste and/or spent fuel as an action prior to provision of acceptable disposal facilities. This implies the need to develop storage criteria, similar to waste acceptance criteria, and to share technical information on waste behaviour over prolonged periods, waste form performance, container design, monitoring, passive systems, record keeping, etc.

Based on the frequency of public and political concerns being cited in the national presentations by representatives of Member States, WATEC wondered if enough was being done to bridge the gap between technological issues and public confidence and saw a role for the IAEA in assisting this process in close collaboration with other international organizations, e.g. OECD/NEA. In this context the importance of substantial progress in solving waste management and particular disposal tasks has been stressed for the future of nuclear power.

WATEC was strongly supportive of the work of the Contact Expert Group (CEG, see Subsection 12.2) and the Spent Sealed Radioactive Sources (SRS) initiatives (see Section 9). These activities are absolutely vital to the area of the IAEA (furthering and preserving peaceful uses of radiochemistry, etc.) and in answering critics of the nuclear industry who target waste as an issue. This is a key area where, for example, the SRS work has an impact in real risk to life as a result of historic activities.

Naturally Occurring Radioactive Material (NORM) waste is now being recognized as a problem requiring attention in many national programmes and WATEC welcomed the work of the Waste Technology Section (WTS) in this area and looked forward to its continuation.

WATEC insisted on Technical Co-operation (TC) activities as being a vital and visible part of the Agency's programmes. TC projects provide insight on needs for Agency publications, etc. in developing countries. Furthermore, these projects provide advanced warning of needs in developing countries.

WATEC also noted that there were clear indications of both the OECD/NEA and the EC working closely with the IAEA to remove much of the potential overlap that raised concerns at previous meetings.

12.1.2 Waste Safety Standards Committee (WASCC)

The WASSC, chaired by Mr. Luc Baekelandt of the Federal Agency for Nuclear Control, Belgium, met in March and September 2003. Each meeting included a joint session with the Radiation Safety Standards Committee (RASSC) to discuss issues of common interest.

One of the major issues discussed by RASSC and WASSC during 2003 was the proposed safety guide specifying levels of activity concentrations that can be used in the practical application of the concepts of exclusion, exemption and clearance established in the International Basic Safety Standards for protection against ionizing radiation and for the safety of radiation sources (DS161). (see Subsection 3.1).

The new overall structure of the safety standards and the action plan on the IAEA safety standards were also discussed extensively. Currently two Safety Requirements and 11 Safety Guides are under development under WASSC lead.

A Safety Guide on Safety Assessment For Nuclear and Radiation Facilities other than Reactors and Waste Repositories ((DS284) to supersede WS-G-1.1) was approved by WASSC for submission to the Commission on Safety Series (CSS) in December 2002, but the process was halted because of the possible overlap with a newly proposed Safety Guide on Safety Assessment of Fuel Cycle and Related Facilities.

In 2003, WASSC approved the Safety Guide on Management of Waste from the Use of Radioactive Materials in Medicine, Industry and Research (DS160) for submission to the CSS.

WASSC approved for circulation to Member States for comment one Safety Requirements on Geological Disposal of Radioactive Waste (DS154). This Safety Requirements is being developed under the co-sponsorship with the OECD/NEA.

WASSC approved the development of a new Safety Requirements on Decommissioning of Nuclear Facilities (DS333).

Approval was given for the restructuring of a Safety Guide on Storage of Radioactive Waste (DS292) taking into account comments received from Member States.

12.1.3 Technical Group on Decommissioning (TEGDE)

Decommissioning is a multi-disciplinary field including aspects ranging from technologies, safety and radiation protection, waste management, financial matters, to land use and others. Such aspects are addressed by distinct programmes of the IAEA. There is a need to ensure that approaches are mutually consistent, reflect best practice, and address the issues according to Member States views and needs. For this purpose, the Technical Group on Decommissioning (TEGDE) was recently established and met for the first time in Vienna from 19 to 22 May 2003. The Terms of Reference for TEGDE are to:

- provide technical guidance on the IAEA's programmatic activities in the area of decommissioning,
- assist and provide guidance to the IAEA in the development of harmonized policies and strategies for decommissioning,
- provide a focal point for the discussion and resolution of technical issues in the field of decommissioning
- prepare, on request, status reports on relevant issues in the field of decommissioning, and

- be a forum for the exchange of information on lessons learned and on the progress of national and international programmes in this field.

At the first meeting, TEGDE participants recognized that significant work had already been done by the IAEA and by other international organizations in many areas of decommissioning and that the way forward required a multi-disciplinary, “cross cutting” approach. It was also recognized that there is a wide range of interested parties associated with nuclear decommissioning.

The overall approach was to identify activities that could assist the IAEA by adding value to its existing and planned programmes, in an effective and timely manner, with the emphasis on seeking early and practical benefits for Member States.

Priority topics were identified and sub-groups were set up, through a voluntary process, to address the top two priorities - Strategy and Funding. These sub-groups conducted their first meetings and produced summary work plans comprising organizational arrangements, scope of task, outline specification of the deliverable (a position paper) and a proposed work schedule.

Pending issues relevant to the two high-priority areas were identified as follows:

Strategy: How can the major factors affect the selection of the strategy?

- What do you do if you do not have funds available?
- What do you do if you do not have a waste management system in place?
- If nuclear subjects are no longer taught in universities, how does this affect the strategy?
- How does the local economy and social issues affect the strategy?
- How does the projected reuse of the facility affect the strategy?
- Are there factors applicable to countries with small programs/resources that must be considered?

Funding: How should decommissioning funds be managed?

- How are the funds collected?
- How can the required funds be reduced?
- When can they be used?
- How do you protect the funds during collection?
- Do you include social needs in decommissioning funding?

It is envisaged that IAEA mechanisms such as the Fact Sheet, the IAEA Bulletin or a Technical Document would be used to publish any TEGDE position paper that the IAEA wishes to place in the public domain.

12.1.4 Overview - IAEA Activities Related to Information Exchange, Technology Transfer and Direct Assistance to Member States in the Field of Radioactive Waste Management

<u>International Meetings</u>

Effective mechanisms for information exchange in radioactive waste management include international conferences, symposia and technical meetings that are organized by the IAEA on a regular basis. These events provide a forum to identify and discuss emerging issues in radioactive waste management that are of common interest to IAEA Member States. Some recent events are described next:

The Stockholm International Conference on Geological Repositories:

In December 2003, an International Conference "Geological Repositories: Political and Technical Progress" was organized and hosted in Stockholm, Sweden by the Swedish waste management organization, SKB [7.37]. The Conference was held in cooperation with the IAEA, OECD,NEA, the EC and EDRAM (see Subsection 12.6). The Conference was also co-sponsored by several national waste management organizations from the US (DOE), France (ANDRA), and Japan (NUMO).

The objective of the conference was to review recent global progress on both policy and technical issues, particularly in reference to a similar Conference in Denver, Colorado in November 1999 [12.1] and to strengthen international collaboration on waste management and disposal issues.

General Findings of the Conference

Regarding technological challenges, there is a widely held view that progress is continuously being made, to the point that technological challenges to geological disposal can be considered to have been solved. Although technological advances will continue to be made, many consider the technology to be essentially mature. By contrast, socio-political aspects and the relevant decision-making processes continue to be seen as areas where further significant progress is needed. In addition, although technological advances in one country may have universal application, socio-political issues are closely connected to particular cultural and legal systems and therefore advances made in one Member State may require significant modification before they could be applied in another. It was also noted that the common assumption that the future (say 20-50 years from now) may be treated as a continuation of the present is a more plausible assumption in the technological domain than in the socio-political sphere. There is, therefore, a need for flexible approaches that can be modified as, and when, required.

Session on long-term safety and security of geological disposal

This session reviewed the progress made and some of the lessons learned since the 1999 Denver Conference dealing with both safety and security. In 1999, the concept of long term "safety case" vis-à-vis performance assessment of disposal facilities was put forward, which was accepted internationally and further developed thereafter. Since then a few major safety studies have been finalized, international peer review of these studies have taken place as well as many workshops and other initiatives regarding the long term safety case.

The Conference heard that the distinction between the performance assessment for a geological repository and the subsequent safety case for that facility (which incorporates the results of the performance assessment) was now generally accepted. Since the Denver conference in 1999, a number a safety studies had been completed and subjected to international peer review. Several other initiatives concerning aspects of the long term safety case have been conducted, e.g. under the auspices of international organizations such as the NEA. Safety requirements for geological disposal have been developed by the IAEA in collaboration with NEA and these are expected to be published shortly. These requirements are intended to complement the existing framework of relevant international instruments, which include the Joint Convention on the safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [2.1], the IAEA's Safety Fundamentals [6.2] and various recommendations from International Commission on Radiological Protection (ICRP, see Subsection 12.5) concerned with radiation protection in the context of waste disposal.

Session on research and development in geological disposal

It was noted from the presentations that the knowledge and understanding of major processes and phenomena associated with the disposal of radioactive waste in deep geological formations have made significant progress partly thanks to *in situ* observations and testing performed in underground research laboratories. The importance of international cooperation on RD&D issues and its contribution to developing and consolidating the scientific and technical basis on geological disposal was also discussed. International cooperation is especially useful on aspects of research that are generic and not site-specific. These joint activities, which are often performed as multinational cooperation projects, complement national efforts. International organizations such as the IAEA, OECD/NEA and EC should continue to play a major role in providing fora for information exchange and fostering knowledge transfer on geological disposal issues between countries. International data bases such as the OECD/NEA thermo-chemical database, were given as examples of international instruments fostering the exchange of scientific knowledge.

Sessions on stakeholder involvement

The two sessions on stakeholder involvement (one from the implementing organizations' perspective, one from one specific stakeholder responsible for decision-making at the municipal level) reflect the heightened attention that stakeholder participation has been receiving over the past few years. The following observations were made:

- Although the involvement of the non-technical community is experienced by some at some time as an impediment in finding a solution, it turns out to be currently the (only) way to arrive at an acceptable site.
- From the presentations made, it is evident that non-technical events outside the programmes may be show-stoppers for current siting programme evolution: examples are drastic governmental policy changes, statements inspired by election opportunism, reorganizations, foreign statements contradictory to agreed national positions (e.g. issues such as trans-boundary movement of waste and multinational repositories).
- Experience and considerations, as presented in the sessions on stakeholder involvement, have shown that repository siting programmes rely on:
    - a clear long term strategy and support of that by government and policy makers,
    - recognition of the responsibilities of all parties' stakeholders,
    - a commitment by all involved parties,
    - a flexible step-by-step decision-making process, and
    - a structured process of interaction.

<u>Research and Development</u>

Article III of the IAEA's Statute states that the Agency is authorized to encourage and assist research on, and development and practical application of, atomic energy for peaceful purposes throughout the world and to foster the exchange of scientific and technical information, as well as the exchange of scientists in the field of peaceful uses of atomic energy. The Agency's co-ordinated research activities are designed to contribute to this mandate, by stimulating and coordinating the undertaking of research by scientists in IAEA Member States in selected nuclear fields.

The Agency supports research mainly through Co-ordinated Research Projects (CRPs), which bring together research institutes in both developing and developed countries to collaborate on the research topic of interest [12.2]. The research that is supported encourages the acquisition and dissemination of new knowledge and technology generated through the use of nuclear technologies and isotopic techniques in the various fields of work covered by the Agency's mandate.

The results are freely available to Member States and the international scientific community through dissemination in the Agency's scientific and technical publications and in other relevant international or national journals. Where it is practical and relevant, the knowledge gained through CRPs is used to enhance the quality of projects delivered to Member States through the Agency's Technical Cooperation Programme (described later in this subsection).

The CRP web site contains a utility for searching for research projects (see Figure 12-1 for a search in the field of radioactive waste management).

Figure 12-1: CRP Search Utility

Research is implemented according to policies and procedures approved by the Director General of the IAEA. Information on these can be found in the Information Letter for the current year, which can be found at the web site shown in Figure 12-1. The Agency's principle role is to act as the sponsoring and co-ordinating body for research on selected topics carried out by selected participating institutions. The Agency designates a Project Officer for the CRP, usually from its technical staff, who will liase with the persons nominated as Chief Scientific Investigators for the participating institutes. Between them, they manage and liase on the research programme, which has a duration normally of between 3 and 5 years. The Agency's Research Contracts Administration Section of the Department of Nuclear Sciences and Applications is responsible for co-ordinating and administering the CRP financial and contractual arrangements.

<u>Technical Assistance</u>

The IAEA' Technical Cooperation (TC) Department [12.3] is a specialized organization within the United Nations system that helps to transfer nuclear and related technologies for peaceful uses to countries throughout the world.

The TC Programme disburses more than $70 million worth of equipment, services, and training per year in approximately 100 countries and territories that are grouped into five geographic regions.

The TC Department works in full partnership with Technical Officers from the Technical Departments [12.4] within the Agency and project counterparts in the recipient Member States. In addition, TC collaborates with the World Bank and other organizations to plan and execute projects in harmony with Member States' needs.

Through training courses, expert missions, fellowships, scientific visits, and equipment disbursement, the TC Programme provides the necessary skills and equipment to establish sustainable technology in counterpart countries or regions. With more than 800 on-going projects, the TC Programme strives to have an impact on Member State problems that can be solved with nuclear technology. See Figure 12-2 for an overview of TC Programme funding.

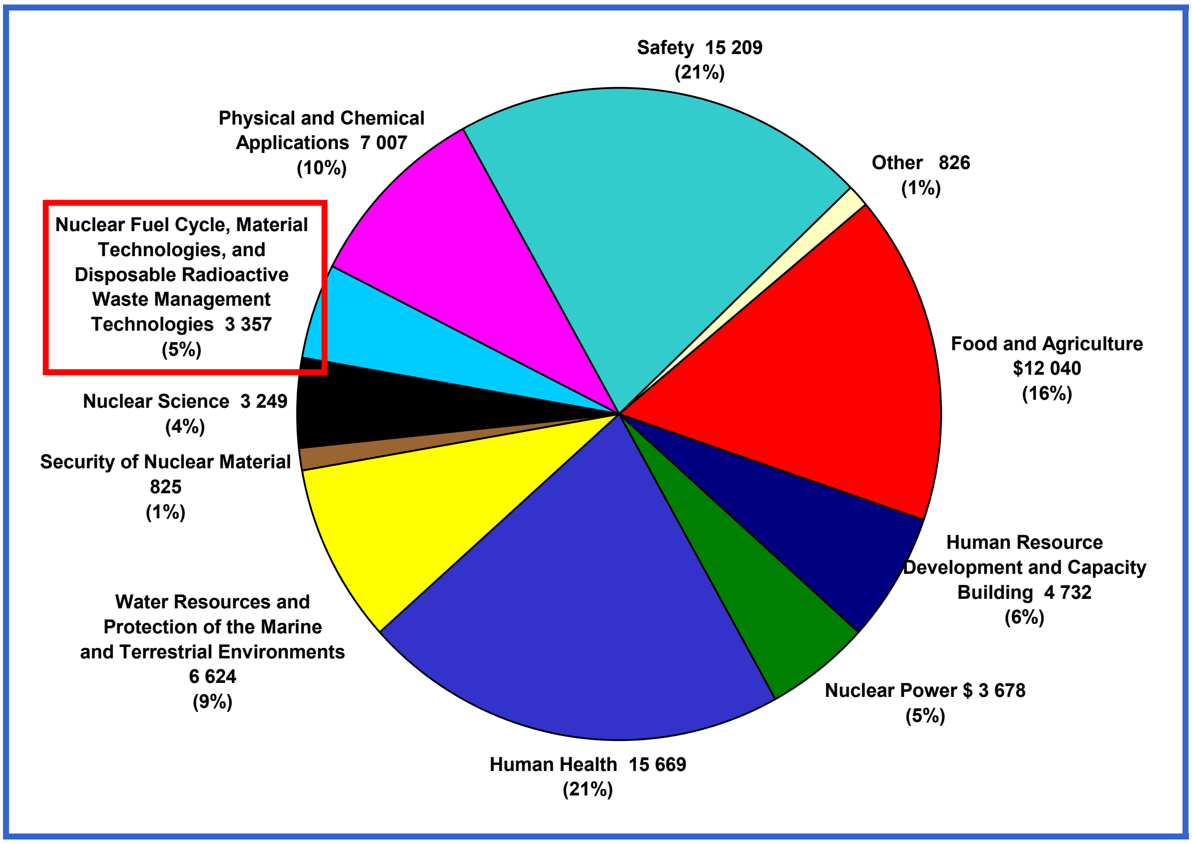
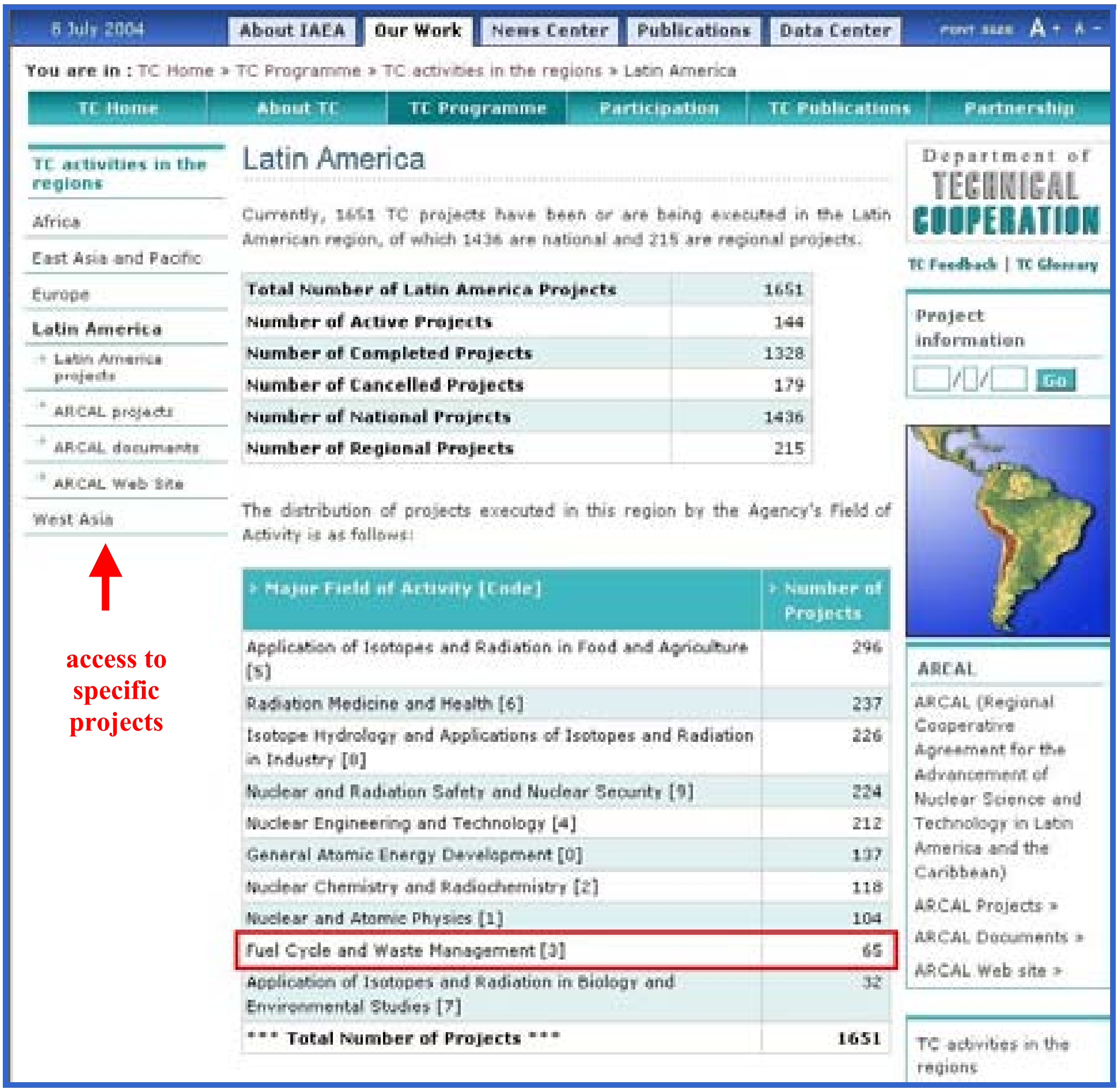


Figure 12-2: Distribution of TC Funding by Programme - 2003 (thousands of dollars)

For information on TC projects, the reader can do the following:

- access web page http://www-tc.iaea.org/tcweb/tcprogramme/default.asp
- select one of the five regions (Africa, East Asia and Pacific, Europe, Latin America, or West Asia); see Figure 12-3 for an example



Total Number of Latin America Projects	1651
Number of Active Projects	144
Number of Completed Projects	1328
Number of Cancelled Projects	179
Number of National Projects	1436
Number of Regional Projects	215

Major Field of Activity [Code]	Number of Projects
Application of Isotopes and Radiation in Food and Agriculture [5]	296
Radiation Medicine and Health [6]	237
Isotope Hydrology and Applications of Isotopes and Radiation in Industry [8]	226
Nuclear and Radiation Safety and Nuclear Security [9]	224
Nuclear Engineering and Technology [4]	212
General Atomic Energy Development [0]	137
Nuclear Chemistry and Radiochemistry [2]	118
Nuclear and Atomic Physics [1]	104
Fuel Cycle and Waste Management [3]	65
Application of Isotopes and Radiation in Biology and Environmental Studies [7]	32
*** Total Number of Projects ***	1651

Figure 12-3: TC Projects in Latin America – Fuel Cycle and Waste Management Highlighted

Technical Advisory Services

Upon request from a Member State, or an organization within a Member State, the Agency undertakes the responsibility of convening an international panel of experts and performing an independent peer review according to the terms of reference established by the requesting Member state or organization. The mechanisms used for this purpose are (a) review of source material (see Reference [12.5] for an example of source material), (b) technical exchange with experts of the requesting Member State or organization in a Waste Management Assessment and Technical Review Program (WATRP) meeting, and (c) preparation of a review report with findings, conclusions and recommendations.

The advantage of such a peer review for the requesting Member State or organization is obtaining independent international experts' opinions and advice on (a) proposed or ongoing radioactive waste management programmes, (b) planning, operation or decommissioning of facilities, or (c) regulatory matters. WATRP can contribute to improving the confidence level of waste management systems planned or in operation, and help to ensure that the systems perform in a safe and reliable manner. WATRP can also assist in improving public acceptability of national programmes.

Recent WATRP reviews that have been performed are:

- Republic of Korea (2002), to review the R&D programme for the disposal of HLW in Korea;
- US Department of Energy (2001), to review the Total System Performance Assessment supporting recommendation of the Yucca Mountain site for a national geologic repository for spent nuclear fuel and HLW (jointly with OECD/NEA)
- Hungarian Atomic Energy Commission (1999), to review Hungarian work on selecting a site for Low and Intermediate Level Waste Disposal
- US Department of Energy (1997), to review the 1996 Performance Assessment of the US Waste Isolation Pilot Plant (jointly with OECD/NEA)
- France (1996), to review the Management of short lived waste in France as seen through the Centre de l'Aube Experience

In 2004 (May 17 to 21), a WATRP review of the Czech Republic's programme on geological repository development was conducted (see Reference [12.5]). The report was under review at the time this Status and Trends report was written.

A WATRP report is the property of the requesting organization, for use at its own discretion, and will be kept confidential by the Agency and the WATRP team. Publication of the report must have the permission of the requesting organization. The WATRP service has been established in such a way that Member States pay for the costs involved. Requests for WATRP services are initiated by a formal request from Member States or an organization within a Member State to the Director General of the IAEA.

12.2 The Contact Experts Group

The IAEA Contact Experts Group (CEG) on Radwaste Projects in the Russian Federation was established in 1996 to coordinate and promote international cooperation on spent fuel (SF) and radioactive waste (RW) management in Russia. At the time this report was written, the CEG was comprised of twelve countries (Belgium, Canada, Finland, France, Germany, Italy, Netherlands, Norway, Russian Federation, Sweden, United Kingdom, and United States of America) and four international organizations: European Commission, International Institute for Applied Systems Analysis, International Science and Technology Center, and the IAEA. The CEG Secretariat is operated by the IAEA.

During regular plenary meetings, CEG members discuss major cooperation activities and review new proposals for cooperative projects, which require urgent international support. In order to provide informational support to the CEG member-countries and other potential donors CEG maintains a database on cooperative projects and a website [12.6].

At the moment, the main priorities of the CEG are dismantling of retired nuclear submarines (NS) and remediation of ex-naval coastal bases. In order to facilitate initiation of new projects in these areas CEG organized a number of workshops dedicated to specific issues:

- two workshops on remediation of the Andreeva Bay SF and RW storage facility,
- workshop on problems of dismantling multipurpose NS, and
- workshop on remediation of ex-naval base at Gremikha

At these workshops, the Russian side presents detailed information on the problems that exist and gives concrete proposals for cooperation in the future. The Western side shares its experience in similar activities and proposes techniques and methods to solve the issues. As a result of these workshops a number of projects have been initiated in Andreeva Bay (in the area of improvement of the site infrastructure under Norwegian assistance, management of SF under UK assistance, management of solid radioactive waste under Swedish sponsorship), and contracts were signed for dismantling of two NS under Norwegian funding and two submarines under UK funding. The 17th CEG plenary meeting (November 2003, Murmansk, Russian Federation) recognized the CEG workshops as a useful tool for extension of international cooperation and decided to organize two more CEG workshops in 2004:

- a workshop on environmental impact and risk assessments as applied to the NS dismantling and the remediation of sites, and
- a workshop on methods and techniques for RW management applicable for remediation of isolated nuclear sites

After signing of the Framework Agreement on Multilateral Nuclear Environmental Programme in Russia (MNEPR), which took place in May 2003 in Stockholm, the Northern Dimensions Environmental Partnership (NDEP) support fund administered by European Bank for Reconstruction and Development became operational and preparatory activities for specific contracts under this fund are now under way. When this Status and Trends report was written, the fund had accumulated about €160 million for nuclear clean up in north-western Russia. The first contracts also have been signed under the Global Partnership Programme of G8 countries and much more cooperative activities are expected to be started soon. In order to assist in coordinating these programmes, the CEG proposes its services as a technical advisor and project facilitator for managing bodies of all bilateral and multilateral programmes in the area of radioactive waste management in Russia.

12.3 Activities of the EC

based on input provided by Mr. S. Webster and Mr. D. Taylor,
Directorate General – Energy and Transport, European Commission and
Mr. Michel Raynal
Directorate General – Research, European Commission

The “nuclear package” [12.7], in particular the proposed Waste Directive [2.6] and the decommissioning aspects of the proposed Safety Directive [12.8], have been at the centre of many of DG-Energy and Transport’s activities in this field during 2003. The year saw both proposals being considered in depth by the Atomic Questions Group (AQG) of the European Union (EU) Council of Ministers (under the Presidency of Greece and then Italy), though no agreement has yet been reached by the Member States. The proposals were also debated by the European Parliament, with both texts eventually being approved with amendments in a vote in early 2004. However, the Parliament’s role in the legislative process is only consultative. At the start of 2004, the EU Presidency passed to Ireland. While the package is continuing to be given a high priority within the AQG, a timetable for adoption by Member States remains uncertain.

Despite the preoccupation with the package during 2003, other routine activities were also carried out by the Commission’s services, including the collection and dissemination of data and information that was a feature of the old Plan of Action in the field of radioactive waste. In April 2003, the Commission published the 5th Situation Report on the status of radioactive waste management in the EU. This presents, mainly in the form of tables, the status in current EU Member States and (for the first time) in Candidate Countries of Central and Eastern Europe at the end of the year 2000. The report shows that production of waste continues to decline as a result of waste minimization practices in the low-level categories. The report also shows the quantities of waste (by country and by category) already disposed of (or for which a national disposal route is available) and the quantities of waste in storage pending the availability of a disposal route. The report is available only in electronic form from the Commission’s Website [12.9].

In January 2003, the Commission published the results of a study on the management of spent sealed radioactive sources (SRS) in Bulgaria, Latvia, Lithuania, Romania and Slovakia (EUR20654 – report available only in electronic form: [12.10]). This study was commissioned to look at the regulation and management of spent SRS in five of the Central and Eastern European Countries that are candidates to join the EU. It supplements a previous report (EUR19842) that covers five other candidate countries from this region and earlier reports dealing with the situation in the Russian Federation and the EU Member States. Work in this area has contributed to the development of new EU policy initiatives regarding management of spent SRS, especially high-activity sources. This culminated in the adoption by the EU Council of Ministers on 22nd December 2003 of Directive 2003/122/Euratom on the control of high-activity sealed radioactive sources and orphan sources [12.11].

The Commission's expert group on radioactive waste management (the Advisory Committee on Programme Management) met twice during 2003. On both occasions the main topic of discussion was the proposed Waste Directive. The EU candidate countries were also invited to attend these meetings. The Waste Directive was also the focus of discussions at the two meetings of the Club of Waste Management Agencies ("Club of Agencies"). This group, for which the Commission provides the Chairman and the Secretariat, met in Tarragona, Spain, and Peine, Germany. At the first meeting, the Club produced an "opinion" on the Waste Directive. Both meetings were followed by a technical visit, the first to see the status of decommissioning of the Vandellos-1 nuclear power plant and the second to the Konrad mine, a licensed facility for the disposal of non-heat generating radioactive waste. The Commission also provides the Secretariat for the "Forum of (radioactive waste management) Regulators". This met once in 2003, the main topic being the regulatory implications of the Waste Directive.

In June 2003, a meeting was organized to update information and to exchange views on the national schemes for the funding of decommissioning of nuclear installations. Eleven States (both existing and future members of the EU) participated together with a representative of the IAEA. The meeting also discussed in some detail both the Safety and Waste Directives. On 4th June 2003, the European Parliament adopted a resolution on the internal electricity market that involves a compromise on the matter of decommissioning funds. The Commission has stated the importance of ensuring that these resources are used transparently and for the intended purposes only, and as part of the compromise the Commission confirmed its intention of drafting an annual report on the use of funds set up for decommissioning and waste management in connection with the Euratom Treaty. The format and modalities of this reporting will be established by DG-Energy and Transport during 2004.

Also in the area of decommissioning, DG-Energy and Transport has become increasingly involved in the activities of the International Decommissioning Funds, set up to assist Lithuania, Slovakia and Bulgaria in the decommissioning, following early closure, of NPPs at Ignalina, Bohunice and Kozloduy. These funds are managed by the EBRD (European Bank for Reconstruction and Development), though as the principal donor, the Commission, though DG-Enlargement, plays an influential role. With the winding-up of DG-Enlargement during 2004, these Commission activities will be transferred to DG-Energy and Transport in the case of the funds for Lithuania and Slovakia, both of which become Member States in May 2004.

In the area of international cooperation, involvement continued in the work of the other international organizations and their committees, in particular the IAEA and the OECD/NEA, both in the area of radioactive waste and decommissioning. Of particular importance was the work on safety requirements for geological disposal of radioactive waste being developed as part of the IAEA's Safety Standards Series.

In addition to the above activities, a range of presentations was made in various international forums covering all aspects of radioactive waste management and decommissioning in the European Union, with emphasis on the nuclear package. A representative selection of these – grouped by general topic on the publications page – is available on the Commission's updated nuclear issues website, where all other relevant reports and summaries of activities can also be found [12.12].

<u>Research and Development in Radioactive Waste Management</u>

The Euratom Framework Programme comprises two distinct parts covering "direct" and "indirect" actions. Indirect action is the main mechanism for funding of Community research, technological development and training, whereas direct action involves complementary activities carried out by the European Communities Joint Research Centre (JRC).

The indirect action within the current 6th Euratom Framework Programme (FP6-Euratom), 2002 – 2006, has the following thematic priority areas: fusion energy research, management of radioactive waste, radiation protection, other activities in the field of nuclear technologies and safety. The FP6-Euratom total budget for indirect action is €940M of which €190M is for the "fission" areas. The general breakdown is €90M for the management of radioactive waste, €50M for radiation protection and €50M for other activities in the field of nuclear technologies and safety [12.13].

The total JRC budget for direct action within FP6-Euratom is €290M. Details of the contents and funding breakdown can be found in the document "JRC Multi-Annual Work programme 2003 – 2006" [12.14].

As part of the coordinated EU policy aimed at the establishing of the European Research Area (ERA), the 6th Framework Programme (both the Euratom part and the much larger EC part covering all other areas) has shifted emphasis compared with previous programmes and a range of different funding instruments are now available. In line with the ERA priorities, the focus within FP6 is now on encouraging integration and cooperation through the establishing of larger multi-partner projects, thus creating a "critical mass" of knowledge, expertise and infrastructure in key areas and increasing efficiency and sustainability of the research effort.

In total, nine eligible proposals were submitted within the NUWASTE activity area (two NoE's, three IPs and four STREPs). Following the evaluations by teams of independent experts during the summer of 2003, seven of these proposals were selected for progression to the contract negotiation phase (one NoE, three IPs and three STREPs, of which two were later merged). Contracts are now in place for all these projects – details are in Table 12-1. In addition, work has started in two other projects (see table) following successful proposal submission and contract negotiation. One is a CA under the NUCTECH activity code on education and training, the other is a Specific Support Action (SSA) submitted as part of the parallel Open Euratom Call (see http://fp6.cordis.lu/fp6-euratom/calls.cfm, link to "Euratom Call Open"). Further details on all projects are available on http://www.cordis.lu/fp6-euratom/projects.htm.

First Thematic Call – Fixed Deadline

The first thematic Call for Proposals in the area "Euratom Research and Training programme on Nuclear Energy", covering the "fission" part of FP6-Euratom, was published on 17th December 2002. The deadline was 6th May 2003 and total budget some €67M. The Call reflected the new thinking regarding the structuring of European research in general and made extensive use of the new FP6 funding instruments. As a result, a smaller number of generally larger projects were being sought under the various specific topic headings, each bringing together a greater number of partners. Within the general field of radioactive waste management, the Call requested proposals on the topics listed in Table 12-2.

From January 2004, Euratom funding is also available for the five EU acceding counties that were previously not associated with the Euratom programme – Estonia, Lithuania, Poland, Cyprus and Malta – and for Switzerland, which became an associated country on 1st January. As a result, the funding for some of these projects has been slightly increased with respect to the originally indicated budgets.

Second Thematic Call – Fixed Deadline

The second Thematic Call in the area "Euratom Research and Training programme on Nuclear Energy" was published on 14th November 2003 with a deadline of the 14th of April 2004. Again, all priority thematic areas within the fission programme are covered; the total foreseen budget is €61M.

Within management of radioactive waste, the specific topics are complementary to those addressed by the first Call – see Table 12-3.

Table 12-1: Contracts in Place after the Thematic Call

Activity Code see Note 1	Project title & description	Instrumen	Coordinator	EU contribution / total cost	Start date & duration
3.2.1.1-1	No projects selected				
3.2.1.1-2	**ACTINET-6** Network for Actinide Sciences	NoE	CEA (FR)	€6.35M / €10.5M	1/3/04 4 years
3.2.1.1-3	**NF-PRO** Understanding and physical and numerical modelling of the key processes in the near-field and their coupling for different host rocks and repository strategies	IP	SCK.CEN (B)	€8M / €16.8M	1/1/04 4 years
3.2.1.1-4	**ESDRED** Engineering Studies and Demon-strations of Repository Designs	IP	ANDRA (FR)	€7.32M / €18.1M	1/2/04 5 years
3.2.1.1-5	**COWAM-2** Community Waste Management 2: Improving the governance of nuclear waste management and disposal in Europe	STREP	Mutadis (FR)	€1.2M / €2.33M	1/1/04 3 years
3.2.2.1-1	**EUROPART** EUROpean research program for the PARTitioning of minor actinides and some long-lived fission products from high active wastes issuing the reprocessing of spent nuclear fuels	IP	CEA (FR)	€6M / €10.3M	1/1/04 3 years
3.2.2.1-2	**RED-IMPACT** Impact of Partitioning, Trans-mutation and Waste Reduction Technologies on the Final Nuclear Waste Disposal (merger of two proposals)	STREP	Kungliga Tekniska Högskolan (SE)	€2M / €3.51M	1/3/04 3 years
NUCTECH-2003-3.4.2.1-2	**CETRAD** Coordiation Action on Education in Radiation Protection and Radioactive Waste Management	CA	UWC (University of Wales, Cardiff)	€250K / €303	1/1/04 15 months
NUCHORIZ-2003-3.5.1	**SAPIERR** Support action: pilot initiative for european regional repositories	SSA	Decom Slovakia, spol. S.r.o.	€195K / €353K	1/12/03 2 years

Note 1: NUWASTE-2003 activity code except for CETRAD and SAPIERR

Table 12-2: Topics in the First Thematic Call

Activity Code	Topic addressed (see Note 1)	Applicable instruments (see Note 2)
NUWASTE	***Management of radioactive waste***	
NUWASTE-1	***Research on geological disposal:***	
NUWASTE-2003-3.2.1.1-1	Sustainable integration of European research in geological disposal of radioactive waste	NoE
NUWASTE-2003-3.2.1.1-2	Sustainable integration of European research on actinides	NoE
NUWASTE-2003-3.2.1.1-3	Understanding and physical and numerical modelling of key processes in the near-field, and their coupling, for different host rocks and repository strategies	IP
NUWASTE-2003-3.2.1.1-4	Development and testing of disposal concepts and technologies in Underground Research Laboratories	IP
NUWASTE-2003-3.2.1.1-5	Improving the governance of geological waste disposal	STREP CA
NUWASTE-2	***Partitioning and transmutation and other concepts:***	
NUWASTE-2003-3.2.2.1-1	Partitioning of actinides and fission products from high-level nuclear waste for their transmutation or conditioning in stable matrices	IP
NUWASTE-2003-3.2.2.1-2	Impact of partitioning and transmutation	STREP CA
NUCTECH	***Other activities in the field of nuclear technologies and safety***	
NUCTECH-2	***Education and training:***	
NUCTECH-2003-3.4.2.1-2	Education and training needs for radiation protection and radioactive waste management	STREP CA

Note 1: For full details go to http://fp6.cordis.lu/fp6-euratom/calls.cfm and follow the link to "Euratom Call 2003 – Fixed deadline"

Note 2: NoE = Network of Excellence; IP = Integrated Project; STREP = Specific Targeted Research Project; CA = Coordination Action (full details on http://www.cordis.lu/fp6/instruments.htm)

Table 12-3: Topics in the Second Thematic Call

Activity Code	Topic addressed (see Note 1)	Applicable instruments
NUWASTE	***Management of radioactive waste:***	
NUWASTE-1	***Research on geological disposal:***	
NUWASTE-2004-3.2.1.1-1	Understanding and numerical modelling of the key processes for radionuclide migration through the geological environment for different repository host rocks	IP
NUWASTE-2	***Partitioning and transmutation and other concepts:***	
NUWASTE-2004-3.2.2.1-1	Transmutation of high-level nuclear waste in an Accelerator Driven System	IP

Note 1: For full details go to http://fp6.cordis.lu/fp6-euratom/calls.cfm and follow the link to "Euratom Call 2004 – Fixed deadline"

Call for Expression of Interest

On the 26th November 2003 the Commission published a Call for Expression of Interest in the area "Euratom Research and Training programme on Nuclear Energy" (details on http://fp6.cordis.lu/fp6-euratom/calls.cfm, link to "EOI.FP6.Euratom.2003"). This is providing an opportunity for Europe's research community to help identify priorities for the mid-term revision of the FP6-Euratom work programme in the fission area. The closing date was 19th March 2004. The submitted EOIs will be evaluated by the Commission in collaboration with independent experts and a report will be made available later in the summer.

Projects in FP5-Euratom (1998 – 2002)

Research projects launched under the "fission" part of the FP5-Euratom have either already been completed or will reach completion during the course of the next 12 months. A comprehensive presentation of these projects is available on http://www.cordis.lu/fp5-euratom/src/projects.htm (see Annex II "Safety of the fuel cycle").

"The Euradwaste'04 Conference was held in Luxembourg on 29-31 March 2004 and was an opportunity for the research community to present the results of FP5-Euratom in the area of radioactive waste management. In addition, the sessions on the first day were devoted to socio-political issues and included presentations and panel discussions related to the Commission's proposed Directive on management of spent nuclear fuel and radioactive waste. The full Conference proceedings are available on the Cordis Website:

http://www.cordis.lu/fp6-euratom/ev_euradwaste04.htm

Additional Information

Additional information about radioactive waste management research in the European Union can be found at the following Internet pages:

http://www.cordis.lu/fp6-euratom/home.html

http://europa.eu.int/comm/research/energy/fi/fi_en.html

12.4 Activities of the OECD/NEA

based on input provided by Mr. H. Riotte,
Radioactive Waste Management Committee
Nuclear Energy Agency of the Organization of Economic Cooperation and Development

The general objective of the NEA [12.15] in the field of radioactive waste management is to contribute to the adoption of safe and efficient policies and practices in Member countries, notably through technical feasibility and long term safety studies. In the area of radioactive waste, the NEA programme is guided by its Radioactive Waste Management Committee (RWMC). In 2003, work focused on management of long lived waste with emphasis on institutional, regulatory and technical aspects. The RWMC is supported by three subgroups, the IGSC (Integration Group for the Safety Case), the FSC (Forum on Stakeholder Confidence) and the WPDD (Working Party on Decommissioning and Dismantling).

<u>Safety case and stepwise decision making</u>

A safety case that commands an adequate level of confidence and can usefully support decision making in the stepwise process can play a key role in demonstrating long term safety. While the need for such a safety case is generally acknowledged, the detailed concept needs further clarification. The RWMC is preparing a short document to facilitate a common understanding of what a safety case is and to help explain the purpose and structure of a safety case to external audiences. This work, as well as other RWMC experience, also provides the basis for the draft of a new international safety standard on geological repositories, which will be published as a joint IAEA/NEA Safety Requirements document.

To understand the very different and sometimes complex institutional arrangements set up by Member countries for radioactive waste management, the RWMC Regulators' Forum compiled relevant country information and prepared a synoptic overview.

Although there is common acceptance that the development of a repository is a step-wise process, there is a need to define more clearly the approaches by which the stages of repository development are derived, and to define the requirements in order to progress from one stage to the next. Based on a topical session of the RWMC and earlier work on reversibility and retrievability, a report is being drafted to clarify the concept of stepwise decision making, to address the main challenges and to summarize experience from studies and ongoing work of the FSC. A draft paper, which was presented to the RWMC in March 2003, is under review following further comments received from the FSC. It is planned to finalize the report following approval from the group at the beginning of June 2004.

International peer reviews

In 2003, the NEA also organized an international peer review of the French "Dossier 2001 Argile", which was produced by the French National Agency for Radioactive Waste Management (ANDRA) to describe the research, development and demonstration activities on the disposal of high level and long lived waste in argillaceous formations. The study represents a milestone in the process of studies and research work leading up to support a parliamentary decision on the French waste management programme in 2006.

Another international peer review has been delivered on a report prepared by NAGRA, the Swiss organization for nuclear waste, presenting the safety aspects of a repository project in the Opalinus Clay in Switzerland. The international review team presented its views on whether the Swiss safety case for geologic disposal in Opalinus Clay is consistent with other international disposal programmes and international practices. The report was published in April 2004 and will be used by the Swiss regulator as an input to its own review of the NAGRA study.

Integration of science

Through its IGSC, the RWMC further supported the development of geological disposal with two new projects: the EBS project, co-sponsored with the EC, and the AMIGO project (Approaches and Methods for Integrating Geologic Information in the Safety Case).

The engineered barrier systems (EBS) initiative is a series of workshops intended to improve understanding of how to achieve the integration needed for successful design, construction, testing, modelling and performance assessment of EBS's, and to clarify the role that an EBS can play in the overall safety case for a repository. A first EBS workshop was organized in Finland, in August 2003, to promote common understanding of design requirements and methodologies to develop detailed design specifications. The next workshop is planned to be held in the United States in September 2004. Future workshops will deal with process issues, the role of performance assessment, and design confirmation and demonstration.

The AMIGO project aims to understand the state of the art in the collection and integration of all types of geologic information (e.g. geophysical, hydrogeological, geochemical, structural) in performance assessment (PA) models and the overall safety case. A first workshop was held in Switzerland in June 2003 to address the interface between geosphere and site characterisation, and performance assessment. A second workshop is planned to be held in Canada in 2005.

To ensure the long term safety of geologic repositories, it is important to assess the stability of geosphere conditions throughout time and vis-à-vis external and internal perturbations. These issues were addressed by a workshop on "Stability and Buffering Capacity of the Geosphere for Long-term

Isolation of Radioactive Waste" that took place in Germany in December 2003, and focused on the specific case of argillaceous media.

Stakeholder involvement

The NEA's FSC published an international survey compiling national experience in Public Information, Consultation and Involvement in Radioactive Waste Management and held its third national workshop in Belgium. The workshop investigated "Dealing with Interests, Values and Knowledge in Managing Risk" in the Belgian context of Local Partnerships. As in previous cases, this workshop had direct interaction with local stakeholders and reviewed lessons learned.

Modern societal demands in terms of risk governance and the widespread adoption of stepwise decision-making processes encourage a new set of behaviours and a new understanding of how regulators may best serve the public interest. The FSC therefore analyzed the regulator's evolving role and image in radioactive waste management and published its findings in this area.

Understanding the scientific basis

To secure the scientific basis of its work, the NEA continued to support the development and sharing of quality-assured databases and models as well as the preparation of a reference book on the self-healing features of clays. The FEP database on "Features, Events and Processes" helps to identify, classify and screen the potentially relevant factors for Geologic Disposal of Radioactive Waste. The existing database is under review to further enlarging the database through new safety assessment studies. For the needs of waste management programmes investigating argillaceous media, an FEP database specific to these media has been published (FEPCAT). In addition, a catalogue of characteristics of various specific clays of importance to repository safety was compiled.

The Sorption II Programme is a benchmarking exercise for the different modelling approaches in use by the various organizations. Based on standardized reference cases selected, modelling calculations have been performed by different teams using different codes. The results of the calculations and performance of codes have been analyzed and compared. The final report has been drafted and is currently under review.

Decommissioning

The detailed issues associated with decommissioning strategy selection were addressed at a workshop hosted jointly by the Spanish regulator and implementing agency. This workshop attracted a large array of specialists from 15 countries, including several mayors from municipalities with decommissioning projects. It revealed the parameters considered for decommissioning strategy selection, from the regulator, implementer and stakeholder viewpoints. The RWMC also collected experience in its decommissioning groups to prepare a report on the status, approaches and challenges in decommissioning, which is meant to inform the interested public and to support specialists and policy makers in their work. Other ongoing work includes the safety case for decommissioning and the impact of regulations on the release of materials and sites on the decommissioning process.

Publications

OECD/NEA publications

The French R&D Programme on Deep Geological Disposal of Radioactive Waste - An International Peer Review of the "Dossier 2001 Argile" ; OECD/NEA, Paris 2003.
Programme français de R-D sur le stockage géologique de déchets radioactifs - Revue internationale par des pairs du Dossier 2001 Argile ; OECD/NEA, Paris, 2003.

SAFIR 2: Belgian R&D Programme on the Deep Disposal of High-Level and Long-lived Radioactive Waste - An international Peer Review; OECD/NEA, Paris 2003.

The Regulatory Control of Radioactive Waste Management - Overview of 15 NEA Member Countries; OECD/NEA, Paris 2004.
Le contrôle réglementaire de la gestion des déchets radioactifs – Panorama de 15 pays membres de l'AEN ; OECD/NEA, Paris 2004 [in preparation]

The Regulator's Evolving Role and Image in Radioactive Waste Management - Lessons Learnt within the NEA Forum on Stakeholder Confidence; OECD/NEA, Paris 2003.
Image et rôle des autorités réglementaires dans la gestion des déchets radioactifs - Enseignements tirés par le Forum de l'AEN sur la confiance des parties prenantes; OECD/NEA, Paris, 2003.

Public Information, Consultation and Involvement in Radioactive Waste Management - An international Overview of Approaches and Experiences; OECD/NEA, Paris 2003.
Informer, consulter et impliquer le public dans la gestion des déchets radioactifs - Panorama international des approches et expériences; OECD/NEA, Paris, 2003.

Public Confidence in the Management of Radioactive Waste: The Canadian Context - Workshop Proceedings, Ottawa, Canada, 14-18 October 2002; OECD/NEA, Paris 2003.

AMIGO-Workshop on Building Confidence Using Multiple Lines of Evidence, Yverdon-les-Bains, Switzerland, 3-5 June 2003; OECD/NEA, Paris 2004.

EBS-Workshop on Design Requirements and Constraints, Turku, Finland, 26-29 August 2003; OECD/NEA, Paris [in preparation].

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Management of Uncertainties in Safety Cases – The Role of Risk, Stockholm, Sweden, 2-4 February 2004; OECD/NEA, Paris [in preparation].

Engineered Barrier Systems and the Safety of Deep Geological Repositories – State-of-the-art Report; OECD/NEA, Paris 2003.

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The Handling of Timescales in Assessing Post-closure safety, Lessons learnt from the April 2002 Workhop in Paris, France; OECD/NEA, Paris 2003.
Gestion des Échelles de Temps dans l'Évaluation de la Sûreté en Phase Post-Fermeture, Enseignements tirés de l'atelier qui s'est tenu à Paris, France en Avril 2002; OECD/NEA, Paris, 2004.

Safety of Disposal of Spent Fuel, HLW and Long-lived ILW in Switzerland An International Peer Review of the Post-closure Radiological Safety Assessment for Disposal in the Opalinus Clay of the Zürcher Weinland; OECD/NEA, Paris 2004.

Die Sicherheit der geologischen Tiefenlagerung von BE, HAA und LMA in der Schweiz - Eine internationale Expertenprüfung der radiologischen Langzeitsicherheitsanalyse der Tiefenlagerung im Opalinuston des Zürcher Weinlands; OECD/NEA, Paris 2004.

NEA General Distribution Documents

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Proceedings of the Topical Session on Stakeholder Involvement Tools: Criteria for Choice and Evaluation (4th Meeting of the NEA Forum on Stakeholder Confidence) [NEA/RWM/FSC(2003)4].

4th IGSC Topical Session on "The Potential Impacts on Repository Safety from Potential Partitioning and Transmutation Programme" [NEA/RWM/IGSC(2003)2].

5th IGSC Topical Session on "Observations regarding the Safety Case in Recent Safety Assessments Studies [NEA/RWM/IGSC(2004)3].

FSC Belgian Workshop (November 2003) – Executive Summary and International Perspective "Dealing with Interests, values and Knowledge in Managing Risk" [NEA/RWM/FSC(2004)4].

12.5 Activities of the ICRP

submission drafted by H. Selling, Ministerie van VROM, The Netherlands

The following provides an overview of the aims of the International Commission on Radiological Protection (the Commission) and the way in which its recommendations may be applied. It also discussed the Commission's initiatives on the radiological protection of non-human species.

The Aims of the Recommendations

The fundamental aim of the Commission was set out as follows in the 1990 Recommendations.

"The primary aim of radiological protection is to provide an appropriate standard of protection for humans without unduly limiting the beneficial actions giving rise to radiation exposure. This aim cannot be achieved on the basis of scientific concepts alone. All those concerned with radiological protection have to make value judgements about the relative importance of different kinds of risk and about the balancing of risks and benefits. In this, they are no different from those working in other fields concerned with the control of hazards."

This statement still represents the Commission's position.

The Commission recommends quantitative standards of protection for practices in all normal situations. These standards set restrictions on the individual dose from all sources under control, i.e. the dose limits. It is not always possible to assess very accurately the total exposure of an individual from all the controllable sources under normal situations. It is necessary then to recommend a standard to protect individuals from exposures to an identified source or group of sources. This is the dose constraint, or risk constraint for potential exposures, for that source under each particular circumstance, which can be in either normal situation or abnormal situations.

The Commission recommends restrictions on the exposure of individual workers and members of the public corresponding to the standards of protection. These should be applied to the exposure of actual or representative individuals. Except for the intentional exposure of patients, in normal situations this should be regarded as the basic level of protection that must always be attained.

In abnormal situations, the Commission again recommends quantitative standards for constraints to protect the individual from a given source under each particular circumstance. These constraints represent the level of dose, or risk, where action to avert the dose or risk is virtually certain to be justified.

The standards in both normal and abnormal situations are complemented by the requirement to optimize the level of protection achieved. This is because there is presumed to be some probability of health effects even at small increments of exposure to radiation above the natural background. The Commission therefore recommends that further, more stringent, measures should be applied to each individual source. The primary standard is complemented by the requirement to optimize the level of protection achieved. This calls for all exposures to be as low as reasonably achievable, economic and social factors being taken into account, in the relevant situation. This requirement cannot be defined in general quantitative terms; it calls for judgement about each situation causing exposure of individuals and is the concern of the operating managements and the responsible national authorities.

The Intended Use of the Recommendations

The Commission aims to provide guidance to a wide range of organizations in a wide range of countries and regions. The Commission believes that these bodies have the responsibility to design their own procedures, which may require development of their own internal documents. The Commission's underlying hope is to encourage the widespread development of a protection culture, within the framework of its recommendations, which permeates all the operations involving exposure to ionizing radiation.

ICRP to establish a new Committee for radiological protection of non-human species

The Commission has decided to develop a framework for the assessment of radiation effects in non-human species, based on the concept of reference animals and plants. The proposed system does not intend to set regulatory standards. The Commission rather recommends a framework that can be a practical tool to help regulators and operators demonstrate compliance with existing and future environmental legislation.

At the International Conference on the Protection of the Environment from the Effects of Ionising Radiation in Stockholm, 6-10 October 2003, participating Member States and international organizations supported the approach of ICRP, including the development of reference animals and plants. The Conference also outlined the role of various international organizations in this work, which includes (but is not limited to):

- UNSCEAR, the United Nations Scientific Committee on the Effects of Atomic Radiation, should provide findings on the sources and effects of ionizing radiation in relation to non-human species.
- ICRP should continue to issue recommendations on radiation protection, including specific recommendations for the protection of non-human species.
- The IAEA should mediate the application of this work internationally.

The Commission can, and is prepared, to play the key role, both in developing a limited set of reference animals and plants and in advising on a common international approach.

The Main Commission of the ICRP met in San Carlos de Bariloche, Argentina, 8-9 November 2003, 75 years after the Commission was established. At this meeting, the Commission decided to establish a new Committee for the protection of non-human organisms, thereby showing its commitment for this rapidly developing area. After two terms, the mandates of this committee, Committee 5, will be reviewed to determine its future. The Main Commission also decided that the mandates of the four existing Committees would be reviewed in the next term so as to ensure its relevance for the future.

The Commission also decided to fill its current vacancy by electing Professor R. J. Pentreath of the Environmental Systems Science Centre, University of Reading, UK, as a new Main Commission member and Chairman-elect of the new Committee 5 of ICRP.

12.6 Topical Issue: Overview of EDRAM

The International Association for Environmentally Safe Disposal of Radioactive Material (EDRAM) was established in 1996 by the executives or chairs of radioactive waste management organizations. Its main purpose is to promote the exchange of knowledge, experience and information among its members. EDRAM's specific objectives are to:

- create a forum where strategic questions can be discussed among implementers with a view to supporting their individual approaches on policy issues, particularly as these relate to demonstration of safety and environmental protection to both the general public and to regulatory organizations,
- support national efforts towards site selection and implementation of long term disposal strategies and to promote a common understanding of waste management issues and the internationally recognized principles which apply thereto,
- stimulate and promote coordinated research and development activities, particularly in underground research laboratories,
- define positions and coordinate actions, where appropriate, in dealing with international organizations (e.g. OECD, IAEA, EU), while recognizing the value of open discussions with governments and regulators in such organizations, and
- discuss technical and management matters, particularly with a view to benchmarking and establishing optimum practices, without disrupting existing mechanisms for cooperation on specific projects.

EDRAM members included, at time of writing:

Agence Nationale pour la Gestion des Déchets Radioactifs (ANDRA) - France
Representative: Mr. Yves LE BARS (EDRAM's Chairman)

Bundesamt für Strahlenschutz (BfS) - Germany
Representative: Mr. Helmut RÖTHEMEYER

Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH (DBE) - Germany
Representative: Mr. Hartmut MEYER

Empresa Nacional de Residuos Radiactivos S.A. (ENRESA) - Spain
Representative: Dr. Antonio COLINO

Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle (NAGRA) - Switzerland
Representative: Mr. Hans ISSLER

Nuclear Waste Management Organization of Japan (NUMO) - Japan
Representative: Mr. Kazunao TOMON

Organisme National des Déchets Radioactifs et des Matières Fissiles (ONDRAF) - Belgium
Representative: Mr. Jean-Paul MINON

Ontario Power Generation (OPG) - Canada
Representative: Mr. Ken NASH
Representative: Mr. Veijo RYHÄNEN

Svensk Kärnbränslehantering AB (SKB) - Sweden
Representative: Mr. Claes THEGERSTRÖM
Representative: Mr. Chris MURRAY

United States Department Of Energy - OCRWM (USDOE) - USA
Representative: Dr. Margaret CHU

EDRAM's views on spent fuel and high level waste management were expressed through a pamphlet that was published in February 2004. The pamphlet stated that:

- The burdens and responsibility for taking care of radioactive waste should not be passed on to future generations.
- Radioactive waste management is a social and technical issue.
- There is a need for flexibility and open and ethical involvement of stakeholders in decision-making.
- Development of long term management solutions should proceed irrespective of the future of nuclear power generation.
- Volumes of spent nuclear fuel and high level waste produced are small and manageable.
- Spent Fuel and HLW is being safely stored on an interim basis and can be continued to be safely stored using current practices for many decades.
- Spent Fuel and HLW are highly regulated and subject to multiple oversight authority of governments.
- Many countries have R&D programs on long term spent fuel management to develop improved methods and techniques. Over $10 billion has already been spent engaging over 20 000 scientists worldwide.
- Several countries have concluded that geological disposal is technically safe and feasible. Some countries are implementing geological disposal and have identified potential repository sites.
- Alternative management strategies are being studied in a number of countries, often within a framework of environmental impact assessment.
- A step-wise approach in decision-making is being used to address long term management of spent nuclear fuel and HLW
- Financial provisions are being made for radioactive waste management. Long term costs are recovered from current electricity consumers and not passed on to taxpayers or future generations.

EDRAM usually holds two meetings every year. These meetings provide an opportunity for its Members to exchange in formation on their respective national situations in the area of spent fuel and radioactive waste management. A special session is normally included in each plenary meeting and dedicated to a specific topic presented either by a guest speaker(s) or a working group. In May 2003, at the EDRAM's biannual meeting, held in Valencia (Spain), the special session was on the new approach taken by Canada regarding the decision-making process on high level radioactive waste management with Mrs. Elisabeth Dowdeswell, Chairman of the Nuclear Waste Management Organization (NWMO) of Canada, as guest speaker.

An internal working group on radioactive waste ownership and liabilities was established by EDRAM in early 2003. At EDRAM's second bi-annual meeting held in Stockholm, Sweden in December 2003, the group coordinated by ENRESA, presented an overview of the current situation in each EDRAM country on that particular issue. The scope of activities for the working group was extended in 2004 to include the financing process.

EDRAM's communication and public relations policy consists of the following diverse activities:

- co-sponsoring international events in the area of radioactive waste management, such as the Stockholm International Conference on Geological Repositories in December 2003 (see Subsection 12.1.4),
- keeping close contacts with various stakeholders organizations, such as the European Commission or the Group of European Municipalities with Nuclear Facilities;
- publishing information on spent fuel and radioactive waste issues through its web site, http://www.edram.org, and
- distributing an information leaflet.

<u>References for Section 12</u>

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http://europa.eu.int/comm/energy/nuclear/index_en.html

12.13 Council of the European Union, "COUNCIL DECISION of 30 September 2002 adopting a specific programme (Euratom) for research and training on nuclear energy (2002–2006)"
http://europa.eu.int/eur-lex/pri/en/oj/dat/2002/l_294/l_29420021029en00740085.pdf

12.14 European Commission Joint Research Council, "JRC Multi-Annual Workprogramme 2003-2006" (pp 49-58)
http://www.jrc.cec.eu.int/download/mawp2003-2006.pdf (pp 49-58)

12.15 Nuclear Energy Agency of the Organization of Economic Co-operation and Development home page
http:\\www.nea.fr

13 ACHIEVEMENTS AND CHALLENGES

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

The first Review Meeting of the Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was held at IAEA headquarters from 3 to 14 November 2003. Although not all National Reports prepared by the Contracting Parties contain sufficient practical information on the implementation of their programmes, the questions and answers exchanged and the presentations at the Review Meeting have provided the participants with a unique insight into the status of spent fuel and radioactive waste management activities across the complete spectrum of programmes, from large to very small.

As an outcome of the Review Meeting, the Contracting Parties have agreed that for the safe and successful management of spent fuel and radioactive waste, there needed to be a clear legal framework; a strong and independent regulatory function; competent licensees or operators; clear lines of responsibility and accountability; public involvement in the decision making process; adequate financial provisions; and clear, integrated plans on how spent fuel and radioactive waste will be managed to assure continued safety into the future. All Contracting Parties have recognized that public consultation on radioactive waste management strategies was not only a good practice to follow but was also essential for the development of a successful and sustainable policy.

The comparison of National Reports has shown large variations in the status of national plans for the ultimate management solution of spent fuel and radioactive wastes. While some countries have overall solutions for the management of intermediate or high level wastes, most countries are still considering what approaches to follow and some have not initiated this important process.

The Classification of Radioactive Waste

The classification of radioactive waste remains a challenge to the international community and to the IAEA’s objective to implement a common classification scheme that will facilitate communication among Member States, which has not yet been fulfilled. However, significant progress has been made on obtaining international consensus on the issues of exclusion, exemption and clearance.

Some countries have clearly defined clearance levels based on radiological criteria, with policy statements that material below those levels can be recycled or disposed of with non-radioactive wastes. Other countries have, in addition to general criteria, a case-by-case approach to clearing radioactive wastes. Guidance to national authorities, including regulatory bodies and operating organizations is provided by the recently published IAEA Safety Guide “Application of the Concepts of Exclusion, Exemption and Clearance Safety Guide”, Safety Standards Series No. RS-G-1.7, September 2004 (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1202_web.pdf). The Safety Guide includes specific levels of activity concentrations for both radionuclides of natural origin and those of artificial origin, which may be used for bulk amounts of material for the purpose of exclusion or exemption. It also elaborates on the application of those levels to clearance.

The new Safety Guide will be instrumental in facilitating the international movement of materials that are contaminated with radioactivity in concentrations that are considered not to be of regulatory concern.

Decommissioning

In the coming decades, a large number of nuclear installations will reach the end of their operational lifetimes and will become candidates for decommissioning. While individual technologies have reached maturity across a range of decommissioning aspects, such as characterization, decontamination, dismantling or waste management, further efforts are needed for the integrated management of large scale decommissioning projects with regards to resource optimization.

An increasing awareness of and planning considerations for reuse options for decommissioned sites is an important aspect of the decommissioning process. Early planning for site reuse can facilitate the operation-to-decommissioning transition, reduce the financial burden associated with decommissioning, reemploy workers and specialist staff, and alleviate the overall impact of decommissioning on the local community. The lack of early planning for reuse of contaminated sites after completion of the decommissioning process is often a hindrance to implementing decommissioning in a timely and cost-effective manner. This strategic inadequacy may be caused by insufficient knowledge of worldwide experience on industrial and other site redevelopment opportunities that were exploited successfully. Operators of nuclear facilities, decision makers at government level, local authorities, environmental planners and developers are all important stakeholders in the site redevelopment process.

In parallel with the magnitude of decommissioning programmes, several Member States have established new organizational structures to deal with ongoing and planned decommissioning projects in an integrated and cost-effective manner.

Predisposal

Difficulties have been encountered in a number of countries in proceeding with the development and construction of disposal facilities, mostly geological repositories for high level radioactive waste and/or spent nuclear fuel, and, as yet, no such disposal facilities are in operation. Therefore, waste and spent fuel inventories continue to accumulate in storage facilities and some countries are currently considering much longer term storage periods exceeding several tens of years.

The safe storage of radioactive waste over short periods has been demonstrated by existing facilities, although deficiencies had been observed in some of the older storage facilities and corrective actions were taken or are underway. The storage of radioactive waste and/or spent fuel for much longer periods than initially envisaged may require a reassessment of conditioning and packaging requirements to ensure long term safety. Any reassessment has to consider that stored materials will need to be safely retrieved and transferred to a disposal facility. Another consequence of extended storage, related to economical considerations, is the increased attention paid by waste generators in several countries to innovative waste processing technologies, such as vitrification for low- and intermediate-level waste (LILW), to drastically reduce the volumes of material to be stored.

The steady increase of spent fuel inventories and the resulting long term “nuclear legacy” initiated the search by the nuclear scientific community for solutions aimed at reducing the expected radiotoxic inventory of materials to be disposed of in geological repositories. In the seventies, several countries launched R&D programmes on partitioning and transmutation (P&T) of actinides and long lived fission products. Since 1990, interest in P&T has been revived in Japan by the launching of the OMEGA programme.

More recently, progress has been made by the international community to investigate the impact of P&T technologies on radioactive waste management strategies and to identify the potential consequences on non-proliferation issues and nuclear fuel cycle development. A recent IAEA report provides information for decision makers and the waste management community about potential expectations from P&T in the near future and about the extent to which P&T might influence strategic decisions on the management of high level waste [13.1]. Comprehensive reports, providing detailed technical information on various aspects of P&T, have been issued by several organizations, particularly the Nuclear Energy Agency of the OECD ([13.2],[13.3], the European Commission [13.4], Ente per le Nuove Tecnologie, l’Energia e l’Ambiente (ENEA, Italy) [13.5] and the US DOE [7.30].

Disposal

The examples of repositories for radioactive waste presented in this report illustrate differing national approaches to disposal in Member States, in particular for low and intermediate level waste (LILW). In regard to the disposal of high level waste (HLW) or spent fuel (SF), most countries have opted for geological disposal at depths of some hundreds of meters as their preferred option. However, opinions vary on the most suitable geological environment.

The approaches adopted for managing long lived waste such as reactor graphite, naturally occurring radioactive materials (NORM) and depleted uranium when it is not regarded as a resource, differ from country to country. No wide consensus on the most suitable long term management options for these challenging waste has been reached yet, which could be considered as internationally recommended solutions.

Several tens of disposal facilities for LILW have been implemented worldwide and are being safely operated. However, it appears that the long term performance of some of them, in particular among those developed years ago, does not meet current safety standards and radiation protection requirements and that eventually, their long term radiological and/or environmental impact may become unacceptable depending on post-closure scenarios. As a consequence, various Member States have ongoing programmes to upgrade their existing disposal facilities. Remediation options range from adoption of new waste acceptance criteria and container specifications to building additional engineered barriers, installing cut-off walls or drainage systems, improving cover systems, retrieving and repackaging waste and other measures. The IAEA promotes information exchange, experience sharing and knowledge transfer among Member States through Co-ordinated Research Projects and it provides assistance through its Technical Co-operation Programme.

Recently, a binding international regime for radioactive waste management involving existing facilities and for past practices was established through Article 12 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. This article states that, “Each Contracting Party shall in due course take the appropriate steps to review… …the results of past practices in order to determine whether any intervention is needed for reasons of radiation protection…”. It is anticipated that the Joint Convention will result in reassessments of the safety of certain repositories and that corrective actions will be pursued based on these assessments.

Most currently operating near surface disposal facilities in the various Member States have been designed based on consideration of the characteristics and inventory of waste arisings from nuclear power plants and/or from nuclear applications. Until recently, the disposal of decommissioning waste was not fully taken into consideration in the design of national repositories for LILW.

However, it is now recognized that decommissioning waste has to be factored into the repository development process at the initial conceptual stage of repository planning. This is particularly important when one considers that the waste arisings from the decommissioning of nuclear facilities are significantly different from the conventional waste derived from the operation of nuclear power plants or from nuclear applications. A number of Member States have licensed new near surface repositories dedicated to very low level waste (VLLW). The simplicity of disposal concepts implemented in countries like Japan, Sweden, France, or the US, coupled with minimal conditioning and packaging requirements, makes the management of decommissioning waste very cost-effective.

At the International Conference on Geological Repositories held in Stockholm, Sweden, in December 2003, it was noted that the knowledge and understanding of major processes and phenomena associated with the disposal of high level radioactive waste (HLW) or spent nuclear fuel (SF) in deep geological formations have made significant progress partly due to *in situ* observations and testing performed in underground research laboratories. The importance of international cooperation on research, development and demonstration issues and its contribution to developing and consolidating the scientific and technical basis on geological disposal was emphasized by many participants at the

Stockholm Conference. These joint activities, which are often performed as multinational cooperation projects, complement national efforts.

One of the greatest challenges to the development of geological repositories for HLW or SF is the need to increase public confidence in the long term safety of this waste management approach. In spite of the difficulties related to socio-political acceptance, encountered by many countries with more advanced deep repository programmes, it should be noted that significant progress has been made over the recent years in the implementation of site selection programmes in a few of them. For example, countries like Finland, Sweden, and the USA have advanced their projects to a stage where decisions to commence construction of repositories can be made.

The IAEA has continued to promote international cooperation and effect consensus on geological disposal through activities associated with its Network of Centres of Excellence on Training and Demonstration in Underground Research Facilities. Training courses in geological disposal have been planned and resourced for the next two to three years. On the basis of needs expressed by several Network Members in 2003, there will be an increased emphasis on hands-on training.

Geological repositories, after closure, are expected to achieve adequate long term safety without the need to place reliance on continuing site monitoring. Nevertheless, the need to meet IAEA safeguards requirements is likely to result in long lasting monitoring and institutional controls at the locations of disposal facilities containing spent fuel and other waste subject to safeguards. The implication of safeguards requirements on the design, construction, operation, closure and post-closure of these facilities, taking account of recent work in the Swedish and Finnish disposal projects, is currently being assessed by the Agency in cooperation with its Member States with more advanced geological repository programmes, in particular in the framework of the IAEA's Programme for the Development of Safeguards Approaches for the Final Disposal of Spent Fuel in Geological Repositories (SAGOR).

Multinational cooperation on key aspects of the nuclear fuel cycle is actively pursued by most countries. A number of Member States, in particular those with smaller nuclear programmes and limited resources, have expressed a clear interest in sharing storage and/or disposal facilities for their radioactive waste or spent fuel. In response to their request and in collaboration with those interested in such approaches, the Agency has assessed the technical feasibility and economical viability of these options, defining several possible scenarios of cooperation and identifying the issues to be addressed, mostly institutional and legal, to facilitate the implementation of such facilities [7.22].

Management of Sealed Radioactive Sources

The Management of spent/disused Sealed Radioactive Sources (SRS) is currently one of the IAEA's high priority areas. Although awareness of the need to properly manage sealed radioactive sources has grown in many Member States, a significant number of radioactive sources are found to be out of administrative control every year. These "orphan" SRS pose a risk that needs to be minimized and avoided in order to protect the public against undue exposures.

Based on the findings of the International Conference on Security of Radioactive Sources which took place in March 2003 at the Hofburg Palace in Vienna, the Action Plan on the Safety and Security of Radiation Sources [9.1], initiated in 1999, was revisited and several new actions proposed by the Agency were approved by the Board of Governors and the General Conference. These new actions aim at enhancing the safe and secure management of radioactive sources in Member States and strengthening the control of the most vulnerable and dangerous ones by establishing and maintaining effective national infrastructures. In that respect, Member States are invited to make efforts to follow the principles contained in the Code of Conduct on the Safety and Security of Radioactive Sources (http://www-pub.iaea.org/MTCD/publications/PDF/Code-2004.pdf). All stakeholders involved in the management of sources (manufacturers, suppliers, users, regulators, etc.) have been encouraged to continue their dialogue on the appropriate means of controlling the export, use and return of radioactive sources, and define their roles and responsibilities during the source life cycle.

The International Catalogue of Sealed Radioactive Sources and Devices [13.6] is being developed in the Waste Technology Section and after the terrorist attacks of September 2001 it became part of the IAEA's Nuclear Security Plan of Activities. The Catalogue is considered as a useful tool in implementing the IAEA's comprehensive approach to nuclear safety and security covering all the activities that contribute to providing appropriate control of radioactive sources from causing radiological accidents as well as prevention, detection of, and response to malicious acts with radioactive sources. Significant progress has been made with the aim of finalizing the first version of the Catalogue by the end of 2004. The long awaited first version of the Catalogue should include data on 5000 source models, 5000 device models and 1000 manufacturer/distributors.

Radioactive Waste Management Information Systems

Note: Due to unforeseen circumstances, the publication of this Status and Trends report was delayed for several months after the "final draft" was written. During the delay period, the results of the 2003 data collection with NEWMDB-II were published. Instructions for accessing NEWMDB reports based on the 2003 data collection can be accessed via the link that follows:

http://www-newmdb.iaea.org/help/instructions2003.pdf

The Net Enabled Waste Management Database (NEWMDB), developed and launched by the IAEA in 2001, contains information on national radioactive waste management programmes, plans and activities, relevant laws and regulations, policies and radioactive waste inventories.

One of the major achievements in early 2004 was the launching of NEWMDB-II on the Internet, followed by a data collection cycle. Additional features have been added, such as the "Reading Room". This feature operates as a "portal" to overview information about radioactive waste management in Member States. Each Member State that participates in the NEWMDB can have its own Reading Room. Another new tool recently added is the "Queries Feature" which allows public users to extract information from the NEWMDB based on specified reporting parameters.

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14 ACRONYMS, ABBREVIATIONS, SYMBOLS & EXPRESSIONS

term	meaning
$	dollar (USA)
€	Euro (European Union's common currency)
£	pound (UK)
ACRWM	Advisory Committee on Radioactive Waste Management (Japan)
AECL	Atomic Energy of Canada Limited
AFR	away from reactor (spent fuel storage)
AGR	advance gas cooled reactor
ANDRA	Agence nationale pour la gestion des déchets radioactifs (France)
ANL	Argonne National Laboratories (USA)
AQG	Atomic Questions Group (European Union Council of Ministers)
AR	at reactor (spent fuel storage)
BNFL	British Nuclear Fuels Limited (United Kingdom)
BSS	Basic Safety Standards
CC	Country Coordinator (for the NEWMDB database, IAEA)
CCP	Country Contact Point (for the DRCS database, IAEA)
CEA	Commissariat à l'Énergie Atomique (France)
CEG	Contact Expert Group
Contracting Parties	Contracting Parties to the Joint Convention
CRP	Coordinated Research Project (IAEA)
CSA	Centre de stockage de l'Aube (France)
CSM	Centre de Stockage de la Manche (France)
CSS	Commission on Safety Standards (IAEA)
ČEZ	Czech power utility
D&D	decontamination and dismantlement (or dismantling)
DESA	Department for Economic and Social Affairs (UN)
DOE	Department of Energy (USA)
DRPEM	Department of Radiation Protection & Environmental Monitoring (Sudan)
DRCS	Directory of Radioactively Contaminated Sites (IAEA)
EBS	engineered barrier system
EC	European Commission
EDF	Electricité de France
EDRAM	International Association for the Environmentally Safe Disposal of Radioactive Material
EPA	Environmental Protection Agency (USA)
EU	European Union
EURATOM	treaty that established the European Atomic Energy Community
FEP	features, events and processes
FBR	fast breeder reactor
FSC	Forum on Stakeholder Confidence (OECD/NEA)
GCR	gas cooled reactor
GIF	Generation IV International Forum

term	meaning
HLW	high level waste
HWR	heavy water reactor
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IFE	Institute for Energy Technology (Norway)
IGSC	Integration Group for the Safety Case (OECD/NEA)
ILW	intermediate level waste (not recommended for IAEA publications)
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles (IAEA)
ION	Institute Oncologique National (Haiti)
ISD	indicator(s) of sustainable development
ISD-RW	indicator of sustainable development for radioactive waste management
Joint Convention	The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
JNC	Japan Nuclear Cycle Development Institute
KKN	Kernkraftwerk Niederaichbach reactor (Germany)
KM	knowledge management
LILW	low and intermediate level radioactive waste
LILW-LL	low and intermediate level radioactive waste – long lived
LILW-SL	low and intermediate level radioactive waste – short lived
LLW	low level radioactive waste (not recommended for IAEA publications)
LMU	Liabilities Management Unit (of the NDA, UK)
LRAD	Long Range Alpha Detector
LTP	license termination plan
Minatom	Ministry of Atomic Energy (Russian Federation)
MOX	mixed oxide
MW	megawatt
MWe	megawatt electrical
NDA	Nuclear Decommissioning Authority (UK)
NEA	Nuclear Energy Agency (of the OECD)
NEFW	Nuclear Fuel Cycle and Waste Technology Division (IAEA)
NEWMDB	Net Enabled Waste Management Database (IAEA)
NFC	nuclear fuel cycle
NORM	naturally occurring radioactive material
NPI	Neutron Products Incorporated
NPP	nuclear power plant
NRA	Nuclear Regulatory Agency (Bulgaria)
NRC	Nuclear Regulatory Commission (USA)
NRPA	Norwegian Radiation Protection Authority
NWMO	Nuclear Waste Management Organization (Canada)
NUMO	Nuclear Waste Management Organization (Japan)
OECD	Organization of Economic Cooperation and Development
ONKALO	underground rock characterization facility (Finland)
P&T	partitioning and transmutation
PMC	Pathfinder Mines Corporation (USA)

term	meaning
POSIVA	organization for disposal site characterization and construction and operation of spent fuel disposal facility (Finland)
PWR	pressurized water reactor
QA	quality assurance
QC	quality control
R&D	research and development
RD&D	research, development and demonstration
RADON	network of waste management facilities in the Russian federation or a common name for a type of near surface disposal facility in the former Soviet Union
RASSC	Radiation Safety Standards Committee (IAEA)
RAWRA	Radioactive Waste Repository Authority (Czech Republic)
RECAP	Repository Closure and Post-closure Project (Canada)
RMS	record(s) management system
RSFSF	Regional Spent Fuel Storage Facility
RW	radioactive waste
RWM Registry	Radioactive Waste Management Registry (IAEA)
RWMC	Radioactive Waste Management Committee (OECD/NEA)
SF	spent nuclear fuel (sometimes the acronym SNF is used)
SHARS	sealed high activity radioactive sources
SKB	Svensk Kärnbränslehantering AB (Sweden)
SMUD	Sacramento Municipal Utility District (USA)
SRS	Savannah River Site (USA)
SRS	sealed radioactive sources
STUK	Säteilyturvakeskus, Radiation and Nuclear Safety Authority (Finland)
TC	Technical Cooperation Department (IAEA)
TDS	total dissolved solids
TECDOC	technical document series (IAEA)
TEGDE	Technical Group on Decommissioning
TENORM	technologically enhanced naturally occurring radioactive material (see page 25 and Subsection 4.2)
TFA	"Très Faible Activité" - French for very low activity
the Commission	European Commission
the Community	European Community
tHM	tonnes of heavy metal
TRU	transuranic or transuranium
tU	tonnes uranium
UK	United Kingdom of Great Britain and Northern Ireland
UKAEA	United Kingdom Atomic Energy Authority
UMM	uranium mining and mill(ing)
UN	United Nations
UNCED	United Nations Conference on Environment and Development (1992)
URL	underground research laboratory
US, USA	United States, Unites States of America
VLLW	very low level waste (there is no international consensus on the definition of VLLW)

term	meaning
VLJ	VLJ repository (Finland)
WAGR	Windscale Advanced Gas Cooled Reactor
WASSC	Waste Safety Standards Committee (IAEA)
WATEC	International Radioactive Waste Technical Committee (IAEA)
WATRP	Waste Management Assessment and Technical Review Program (IAEA)
WIRKS	waste inventory record keeping system
WMRA	Waste Management Research Abstracts database (IAEA)
WNU	World Nuclear University

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