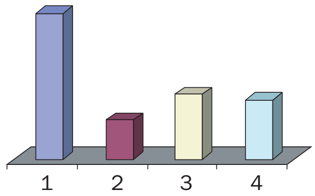
NUCLEAR FUEL CYCLE AND WASTE TECHNOLOGY

PROGRAMME OBJECTIVE

To facilitate the transfer and exchange of information and technology among Member States; to provide assistance and guidance, when requested, on the formulation and implementation of strategies in nuclear fuel cycle related activities and radioactive waste management programmes with due regard to efficiency, safety, environmental soundness and sustainability, and consistency with internationally accepted norms, where applicable, and good practices.

Regular budget expenditure:$4 686 198

Extrabudgetary programme expenditure (not included in chart): $673 718



1. Nuclear Fuel Cycle and Materials: $2 205 366
2. Sources of Radioactive Waste: $596 685
3. Implementation and Application of Radioactive Waste Management Technologies: $986 165
4. Waste Management Information and Technology Transfer: $897 982

OVERVIEW

The Agency's nuclear fuel cycle and waste technology programme covers all aspects of the fuel cycle, from uranium resources and production, through nuclear fuel performance and technology, to spent fuel management. Increasing attention has been given to how the fuel cycle affects the sustainability of nuclear power, and to spent fuel management, particularly spent fuel storage and the increasing inventory of separated plutonium. Thus, the focus this year was on uranium resources and production, including environmental issues, and on spent fuel technology, including long term storage and burnup credit. Major events in 2000 were the publication of the IAEA–OECD/NEA 'Red Book 1999', and the holding of an international symposium on the uranium production cycle and the environment.

Activities in the area of radioactive waste management emphasized waste minimization and facility decommissioning, the implementation of waste management initiatives (with a greater focus on disposal issues), and technology transfer and information exchange. The Agency placed greater emphasis on international co-operation in the geological disposal of high level and long lived wastes. Canada and Belgium offered to make their underground research laboratories available to the Agency to organize international demonstrations and training projects on geological disposal. And the scientific forum during the General Conference in September focused on the technology and safety aspects and future directions of radioactive waste management.

NUCLEAR FUEL CYCLE AND MATERIALS

In 2000, the Agency and the OECD/NEA published *Uranium 1999: Resources, Production and Demand* (the 'Red Book'), the foremost world reference on uranium. Using official information from 49 countries and including statistics on resources, exploration, production and demand as of 1 January 1999, the Red Book provides substantial new information from all major uranium producing centres in Africa, Australia, Eastern Europe, North America and the Newly Independent States, and analyses industry statistics and worldwide projections of nuclear energy growth, uranium requirements and supply.

A symposium in October on the uranium production cycle and the environment addressed long and short term uranium supply issues, impact assessment, socioeconomic effects, safety and regulatory affairs.

"In 2000, the Agency and the OECD/NEA published Uranium 1999: Resources, Production and Demand (the 'Red Book'), the foremost world reference on uranium."

One major message was that environmental issues carry with them an important social dimension. The environmental–social link is particularly significant in areas with strong traditional local cultures, but in all cases mining concerns should establish early communication with other stakeholders, particularly those communities most directly affected. Another issue that was emphasized was that the planned, progressive decommissioning of an operational site is the key to minimizing environmental impacts, satisfying public and regulatory concerns, minimizing operational and decommissioning costs, minimizing corporate liability and building public support.

A CRP on transport models of radioactive substances in primary circuits of water cooled reactors ended in 2000. Models incorporated in nine national codes were evaluated using a blind exercise based on activity measurement data provided by five countries operating PWR, WWER and CANDU power plants. The participants conducted sensitivity analyses to evaluate more specifically the different models and the precise role of each parameter, and identified important improvements that can be made in national models and codes.

The Agency also completed and published a study of stress corrosion cracking in Zircaloy fuel cladding. Pellet-clad interaction, which is a licensing concern for many water reactors, was investigated, as were the effects of creep, temperature, material condition, iodine partial pressure and texture on stress corrosion cracking rates and on the fractography of the resulting cracks. The study can be used in modelling fuel behaviour, and also contains an up to date review of iodine induced stress corrosion cracking of zirconium alloys.

Within the framework of a CRP on hydrogen and hydride degradation of the mechanical and physical properties of zirconium alloys, an Agency study of delayed hydride cracking of pressure tube material led to a very effective transfer of know-how at the laboratory level. Delayed hydride cracking can result in the failure of pressure tubes in CANDU reactors and may also contribute to fuel cladding failure in water reactors. The study participants carried out a round-robin exercise, reporting delayed hydride cracking of CANDU pressure tube material measured in different laboratories. The results show that much of the usual spread in data across laboratories can be dramatically reduced simply by careful experimental controls.

The continuing accumulation of spent fuel is an important concern for the Agency (Fig. 1). New nuclear power plants are coming on line in Asia and Eastern Europe. And in Western Europe and North America existing power plants continue to generate spent fuel. This accumulates in storage facilities and, due to limited pool capacities, has already required re-racking in many pools plus away-from-reactor (AFR) storage. Currently, only a few countries reprocess spent fuel or plan direct

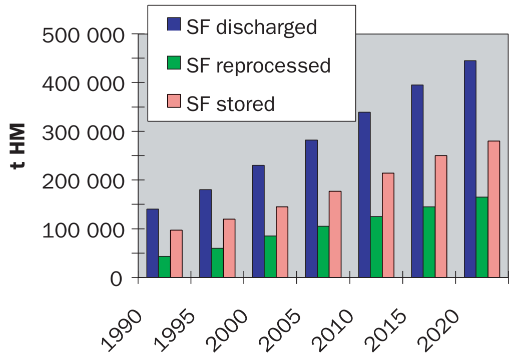


FIG. 1. Projected cumulative generation of spent fuel (SF), measured in tonnes of heavy metal (t HM).

disposal. Most have deferred such decisions and store their spent fuel. The lack of final repositories and the deferral of decisions lead to long, but uncertain, storage periods.

To address these concerns, the Agency examined the requirements for long term storage facilities in a Technical Committee meeting. In addition, a CRP on spent fuel performance assessment and research studied the behaviour of spent fuel and structural materials during long term wet and dry storage. Capacity requirements for future storage are driven by the fact that less than one third of spent fuel will be reprocessed, mainly in Europe. Design requirements for future storage, including materials, equipment and installation, must also take into account the trend to higher fuel burnup (and consequent higher enrichment of fresh fuel) and the use of plutonium in mixed oxide (MOX) fuel. These lead to changing spent fuel characteristics, i.e. higher decay heat and a flatter downward curve over time. This necessitates a longer storage period than is common in many countries with burnup lower than 40 GW·d/t.

On the issue of burnup credit, the Agency held a Technical Committee meeting to report on progress made in burnup credit implementation. Such credits take advantage of changes in the isotopic composition of fuel during burnup that reduce reactivity. The meeting participants observed that the motivation for applying credits in criticality safety applications is generally economic, but burnup credit is also applicable to assessments of public health and safety, resource conservation and environmental quality. These credits also generally make it possible to load more fuel into one transport or storage cask, thereby reducing the number of transports or amount of storage space.

The Nuclear Fuel Cycle Information System (NFCIS) completed its third year of operation. An upgraded client/server database management system was installed to allow faster and more reliable access. A newly developed Internet site allows users from the Agency and Member States to search the NFCIS database and retrieve information on nuclear fuel cycle facilities around the world. Also available is the Nuclear Fuel Cycle Simulation System (VISTA), a newly developed Agency model for calculating and estimating fuel cycle service requirements. The model has been enhanced to include estimates of MOX fuel fabrication requirements and separated civil plutonium inventories. VISTA integrates data from other Agency databases (such as PRIS and the Energy and Electricity Data Bank (EEDB)) in order to estimate fuel cycle service requirements based on various scenarios for each world region. The Agency also developed a new Internet site *(http://www.iaea.org/programmes/ne/video/menu.htm)* that features a library of video films describing nuclear power and the fuel cycle.

“Capacity requirements for future storage are driven by the fact that less than one third of spent fuel will be reprocessed, mainly in Europe.”

SOURCES OF RADIOACTIVE WASTE

The large number of facilities scheduled for retirement in the near future in many Member States has made the subject of waste minimization during decommissioning increasingly important. The Agency published a technical report on *Minimization of Radioactive Waste from Decontamination and Decommissioning of Nuclear Facilities* that analyses the current status of waste minimization during decommissioning, the principles and factors to be considered when selecting a minimization strategy, and the existing options, approaches, developments and trends in waste minimization.

Published information and guidance on the organizational dimensions of decommissioning is considerably more scarce than information on technological aspects. This lack of

"One of the most efficient [waste] minimization options is to recycle and reuse valuable materials and components from different waste streams."

information may be due to perceived differences between privately operated and state owned facilities, or due to variations between countries, but it is possible to establish common rules and recommendations that can be adapted to specific cases. This is important because the lack of guidance on organizational aspects may create the impression that the availability of the required technologies is enough for successful decommissioning. For this reason, the Agency published a review of the planning and management aspects of decommissioning entitled *Management and Organization for the Decommissioning of Large Nuclear Facilities*.

Other activities related to this area included technical co-operation projects that focused on assisting Member States with the drafting and review of decommissioning plans for shutdown research reactors (see Fig. 2). These projects covered a range of strategies — from immediate dismantling (Latvia) to long term safe enclosure (Georgia). In another technical co-operation project focusing on central and Eastern Europe, the Agency brought together international experts to assist in transferring technology and know-how to Armenia, Bulgaria, the Czech Republic, Hungary, Slovakia and Ukraine. The experts first provided information on decommissioning planning and management based on national experiences and then helped draft a technical document to consolidate available information, decommissioning experience, lessons learned and guidance. The document also identifies the resources that need to be provided for decommissioning.

IMPLEMENTATION AND APPLICATION OF RADIOACTIVE WASTE MANAGEMENT TECHNOLOGIES

Waste minimization is a basic component of a modern integrated waste management strategy. One of the most efficient minimization options is to recycle and reuse valuable materials and components from different waste streams. The Agency published a technical document in 2000 that provides comprehensive information on recycling and reusing both radioactive and non-radioactive components of potential waste streams from the entire nuclear fuel cycle. The document includes 'historic waste' as a specific waste stream, and emphasizes that recycle and reuse should be a

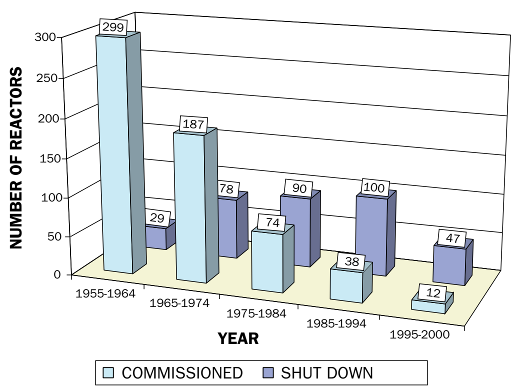


FIG. 2. Double column histogram showing the decreasing number of research reactors commissioned and the increasing number shut down in each decade between 1955 and 1994, and in the half-decade from 1995 to 2000.

consistent part of each national, site and plant specific waste management policy.

Another document, *Handling and Processing of Radioactive Waste from Nuclear Applications,* addresses the pre-disposal management of radioactive waste generated in applications of radioisotopes in research, medicine and industry. Present practices, procedures and techniques for the treatment, conditioning, packaging and storage of radioactive waste are also described, as are the basic principles and factors to be considered when selecting a waste management strategy and processing technology. Finally, the document provides technical information and reference material on different waste processing options.

Management of Radioactive Waste from the use of Radionuclides in Medicine is intended for medical and biomedical establishments and for authorities overseeing medical applications of radioisotopes. This technical document, like the previous document, sets out the principles and factors to be considered when selecting a waste management strategy and processing technology. The document also describes advanced practices implemented in facilities around the world and provides practical guidance and recommendations.

An entire generation of graphite moderated nuclear reactors will need to be decommissioned in the near future, as will other nuclear facilities using graphite for various purposes. However, the excellent mechanical properties and chemical stability of graphite, which are advantages during its lifetime, make the management of graphite waste more difficult. To foster information exchange among Member States having to address this problem, the Agency completed a review of radioactive graphite waste management from the dismantling of nuclear power plants, as well as other nuclear graphite applications.

Near surface disposal of low and intermediate level waste is an option being practised or planned in many Member States, and there is a growing need for additional information and guidance. To meet this need, the Agency assessed the scientific and technological issues involved in order to help Member States to develop, site, implement and assess the safety and performance of disposal systems. Various non-technical questions, including social, economic, institutional, local and national infrastructure, public policy and acceptance issues, were also studied. As part of these reviews, a technical document, *Inspection and Verification of Waste Packages for Near Surface Disposal* was published that describes the concepts of waste package inspection and verification, waste acceptance requirements, and the establishment of a waste package quality assurance/quality control programme.

"Near surface disposal of low and intermediate level waste is an option being practised or planned in many Member States, and there is a growing need for additional information and guidance."

Plans for high level, long lived waste disposal in deep geological repositories raise unique problems owing to the very long time-scales that must be considered. To heighten public confidence in geological disposal and refine long term predictions of the condition of such disposal systems, the Agency published a technical document on methods used to extrapolate short term observations to the longer time periods needed for analysing the isolation of long lived radioactive wastes. Analogue studies represent another approach to evaluating system performance and building confidence in the safety of geological systems. Accordingly, the Agency started a CRP on anthropogenic analogues that will study the processes that have affected ancient artifacts and materials. This can help provide an understanding of how human-made materials will behave in a repository environment over many centuries.

The contribution of monitoring to the long term safety of radioactive waste repositories was the subject of a technical document published by the Agency in 2000. Monitoring is seen mainly as an important way to provide reassurance that a repository is fulfilling its intended purpose, i.e. to isolate waste from the human environment. The document describes possible environmental monitoring objectives at different stages of repository development, the monitoring techniques that might be applied, and the ways that the resulting information might be used.

> ***"An important event in 2000 was the offer by Belgium and Canada to make their underground research laboratories available for international demonstration and training activities under the aegis of the Agency."***

An important event in 2000 was the offer by Belgium and Canada to make their underground research laboratories available for international demonstration and training activities under the aegis of the Agency. Several Member States plan to construct such laboratories to develop expertise and hands-on experience with radioactive waste disposal in underground environments. The Belgian and Canadian offers provide an important opportunity to share expertise and promote international consensus among Member States.

WASTE MANAGEMENT INFORMATION AND TECHNOLOGY TRANSFER

Since 1996, the Agency has conducted regional demonstrations on predisposal waste management methods and procedures to provide hands-on training in processing specific kinds of radioactive waste, mostly from medical, research and industrial radioisotopes. In 2000, the first cycle covering Latin America, East Asia and the Pacific, and Eastern Europe and Middle East was completed. The series of demonstrations for the Russian Federation is still under way, and their scope is being expanded to add emphasis to quality management aspects of radioactive waste management. In the last four years, these demonstrations have reached more than 100 participants from 50 countries.

The number of radium conditioning operations increased by 50%, and several Member States provided new expert teams in 2000. In Asia, the Agency qualified new expert teams from the Republic of Korea and Pakistan, and carried out successful operations in Sri Lanka, Myanmar and Bangladesh. In Africa, operations were conducted in Madagascar, Egypt, Sudan, Mauritius and Tunisia. In Latin America, radium sources were conditioned in Venezuela. The few Latin American countries whose radium sources have not yet been conditioned still use radium for nuclear applications. Before the Agency can assist with conditioning, these countries will have to terminate such applications and collect all radium sources.

The radiation source accident in Thailand in early 2000 illustrated the continuing need for increased information and care in handling such sources. A technical document, on the *Handling, Conditioning and Storage of Spent Sealed Radioactive Sources*, was published in 2000 that provides information on both sealed source conditioning procedures and various storage options. Another document on *Management for the Prevention of Accidents from Disused Sealed Radioactive Sources* is in the process of being published.

Remaining with the subject of sealed sources, the Agency developed the computer software and began collecting and entering the data for an International Catalogue of Sealed Radioactive Sources and Devices. Member States have been asked to provide information for this resource, which will be supplemented by information from commercial catalogues and Internet databases. The catalogue, in its final form, will contain technical information about sealed sources, including design features and illustrations, and data on manufacturers and distributors, including addresses and company histories. It is intended as a tool for identifying orphan sources and old devices containing sealed radioactive sources.

The Agency serves as the Secretariat for the Contact Expert Group (CEG), which co-ordinates the management and disposition of spent fuel and radioactive waste in the Russian Federation, including waste from submarine reactors. By the end of 2000, 180 submarines had been taken out of service, of which 115 still had spent nuclear fuel on board. The rate of defuelling has increased with financial support from Japan, the USA and Western European countries. Four submarines were defuelled in 1998, eight in 1999, and 18 in 2000. Another 20–21 are scheduled for defuelling in 2001. The problem of liquid radioactive waste treatment has been solved by upgrading existing facilities at Atomflot, in the northwest part of the Russian Federation, near Murmansk, and by commissioning a new floating treatment facility in the far eastern part of Russia. With the participation of Norway and the USA, dual purpose metal–concrete casks for transportation and interim storage of spent nuclear fuel are now in use. As of October 2000, 28 casks had been manufactured. A new train has also been built to transport the spent fuel to the Mayak reprocessing plant. And in 2000, the Netherlands joined the CEG, bringing its membership to 13.