Nuclear Fuel Cycle and Materials Technologies

Objective

To enhance and further strengthen the capabilities of interested Member States for policy making, strategic planning, technology development and implementation of safe, reliable, economically efficient, proliferation resistant, environmentally sound and secure nuclear fuel cycle programmes.

Uranium Production Cycle and the Environment

Uranium mine production is expected to increase in a number of countries, including Australia, Canada, Kazakhstan, Namibia, Niger and the Russian Federation, to meet the needs of an anticipated increase in demand. Exploration activities continued in 2010 in many countries, and additional resources were identified in Australia, Canada and Namibia. However, several challenges remain despite strong market conditions. These include high production costs, a weak supply chain, ageing facilities and workforce, shortages of new and experienced staff for expansion, and geopolitical issues.

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The 23rd edition of the joint OECD/NEA–IAEA report *Uranium 2009: Resources, Production and Demand*, commonly known as the 'Red Book', was published in 2010. Identified conventional uranium resources recoverable at a cost of less than $130 per kilogram of uranium (kg U) are currently estimated at 5.7 million tonnes of uranium (Mt U). This is an increase of over 0.2 Mt U relative to 2007, due mainly to increases reported by Australia, Canada and Namibia. There are an additional 0.7 Mt of identified conventional uranium resources recoverable at costs between $130 and $260/kg U. For reference, the spot price for uranium in 2009 fluctuated between $110 and $135/kg U with a very gradual downward trend. The report indicates that at the estimated 2009 rate of consumption, the projected lifetime of the 5.7 Mt of identified conventional uranium resources recoverable at less than $130/kg U is almost 90 years.

The Agency was requested by Brazil to send a Uranium Production Site Appraisal Team (UPSAT) to undertake a peer review of operations at the uranium mine at Caetité (Fig. 1). UPSAT peer reviews may be requested by any Member State for any part of their uranium production cycle operations. The UPSAT mission to Caetité took place in February. The team comprised five experts — from Australia, Canada, the Czech Republic, France and the Agency — who

FIG. 1. UPSAT members interviewing staff at the Caetité uranium mine in Brazil.

reviewed all aspects of the uranium mining and processing operations, including future expansion plans and proposed changes in both mining and processing methods. The team concluded that the operations at Caetité are run in a clean and efficient manner with no evidence of adverse environmental impacts outside the mining licence area, and provided recommendations on the management of groundwater at the mine site. It also noted that the work force at the facility was motivated and conscientious and identified opportunities for the personnel to benefit from international good practices. The final report was completed in 2010 and will be published in 2011.

Nuclear Power Reactor Fuel Engineering

Several years of effort collecting and compiling information on fuel failures culminated in the publication of a *Review of Fuel Failures in Water Cooled Reactors* (IAEA Nuclear Energy Series No. NF-T-2.1). The review, covering 96% of the world's water cooled reactor fleet, analysed the mechanisms and root causes of fuel failures, reviewed methods to detect and examine failures, and recommended prevention and remediation measures.

The Agency also published the results of a CRP on *Delayed Hydride Cracking of Zirconium Alloy Fuel Cladding* (IAEA-TECDOC-1649), which transferred the technology for testing of fuel cladding to nine Member States and investigated the cracking behaviour of six commercial cladding alloys. Also published were the proceedings of a technical meeting on *Advanced Fuel Pellet Materials and Fuel Rod Design for Water Cooled Reactors* (IAEA-TECDOC-1654).

The Post-Irradiation Examination Facilities Database (*http:www-nfcis.iaea.org/PIE/PIEMain.asp*), which is administered by the Agency in cooperation with the HOTLAB Association, was substantially revised with the addition of new members and updated information. The joint OECD/NEA–IAEA International Fuel Performance Experiments Database was also updated, with new experimental data on high burnup fuel performance under normal and transient conditions. These data were derived from an ongoing CRP on 'Fuel Behaviour Modelling: FUMEX-3'.

Spent Fuel Management

Currently, less than 25% of discharged fuel is reprocessed, and the implementation of disposal facilities for spent fuel or high level waste has been delayed in most Member States. Consequently, there are growing inventories of spent nuclear fuel (SNF), and spent fuel will have to be stored for longer periods than initially intended, with storage times possibly extending beyond 100 years (Fig. 2).

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Together with the OECD/NEA, the Agency organized an international conference on 'Management of Spent Fuel from Nuclear Power Reactors', which was attended by more than 200 participants from over 40 countries as well as 4 international organizations. The conference concluded that repositories for either SNF or high

FIG. 2. Spent fuel dry (left) and wet (right) storage facilities.

level waste from recycling facilities remain at least a decade away. This will necessitate an increase in both the amount of SNF in interim storage and the length of time SNF will be stored. The participants felt that more work was needed to strengthen confidence in the integrity of SNF for these long periods of storage. The conference also identified the need for additional work to be done on burnup credit for spent fuel from power reactors, fuel behaviour in dry storage, and the behaviour and safety of high burnup fuels and MOX fuels in long term storage. It stressed the importance of greater international cooperation on R&D and progress towards harmonized safety regulations.

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The Agency started the third phase of the CRP on 'Spent Fuel Performance Assessment and Research' (SPAR-III). SPAR-III will investigate potential deterioration mechanisms of spent fuel elements stored for long periods.

A CRP on 'Spent Fuel Performance Demonstration' was initiated which will coordinate the collection and analysis of experimental results on the integrity of stored spent fuel.

A new activity on very long term storage of used nuclear fuel was begun to assess the technical, institutional and societal aspects of managing spent fuel for periods of 100 years or longer.

Topical Advanced Fuel Cycle Issues

Member States have pursued activities focused on developing advanced and innovative technologies for safe, proliferation resistant and economically efficient nuclear fuel cycles with the aim of minimizing waste and adverse environmental impacts. One such strategy is the partitioning and transmutation of minor actinides. Rather than merely separating uranium and plutonium from fuel that is being recycled, this process involves the additional chemical separation of elements such as americium, curium and neptunium. The inclusion of these 'minor actinides' in fuel or targets for fast neutron systems results in their fission (transmutation) into less problematic elements, removing their burden from eventual waste disposal scenarios. In 2010, the Agency published an *Assessment of Partitioning Processes for Transmutation of Actinides* (IAEA-TECDOC-CD-1648), which discusses various aspects of partitioning processes in detail with the aim of exchanging information among those involved in studying and developing viable separation methods.

The future growth of nuclear energy and its sustainability will depend on the continued adoption of advanced and innovative technologies in the nuclear fuel cycle. The Agency organized a topical meeting on 'Manufacturing Methods for Advanced Nuclear Fuels' to clarify the present status of and future prospects for the use of advanced technologies in fuel fabrication and to identify challenges facing the development of more innovative applications. The meeting concluded that although there are established methods for manufacturing uranium/plutonium based fuels, more developmental work was needed, particularly for manufacturing highly radioactive minor actinide advanced fuels.

Significant efforts are under way in several Member States such as China, India, Japan, the Republic of Korea and the USA to develop high temperature gas cooled reactors (HTGRs) for process heat, hydrogen production and electricity generation. Research programmes are being pursued in these Member States to predict the behaviour of HTGR fuel under normal and off-normal operating conditions. The Agency organized a technical meeting on high temperature gas cooled reactor fuel and fuel cycles to exchange recent information on technological progress made in various aspects of fuel and fuel cycles for HTGRs, and to identify the major challenges facing the development of fuel and fuel cycles for these reactors. It was concluded that more technological development was needed for the manufacture of multilayer coated particle fuel, advanced techniques for the characterization of coated particles by both destructive and non-destructive methods and irradiation testing. In addition, the Agency published the proceedings of an international topical meeting on *Nuclear Research Applications and Utilization of Accelerators* (Proceedings Series No. 173 (CD-ROM)).

Integrated Nuclear Fuel Cycle Information System

Comprehensive information on worldwide nuclear fuel cycle activities is available through the

FIG. 3. NFCIS coordinators and nuclear fuel cycle experts discussing fuel cycle synergies and sustainability at the spent fuel reprocessing plant in La Hague, France.

Agency's Integrated Nuclear Fuel Cycle Information System (iNFCIS) (*http://www-nfcis.iaea.org/*). In 2010, iNFCIS received more than 600 000 visits from about 12 000 registered users. The on-line information system includes the Nuclear Fuel Cycle Information System (NFCIS), World Distribution of Uranium Deposits (UDEPO), Post-Irradiation Examination Facilities Database (PIE) and Minor Actinide Property Database (MADB). In 2010, a new activity was initiated to collect information on the World Distribution of Thorium Deposits and Resources (ThDEPO).

With iNFCIS it is possible to analyse the different stages, facilities, capacities, interlinkages and synergies related to various fuel cycle options and approaches (Fig. 3). The Agency organized a technical meeting on 'Nuclear Fuel Cycle Information and Synergies for Leveraging Sustainability' in Vienna in December to analyse the potential strengths in the fuel cycle supply chain and to examine early warnings of potential bottlenecks in meeting the increased demands expected in the future.