Nuclear Fuel Cycle and Materials Technologies

Objective

To advance the development and implementation of an increasingly safe, reliable, economically efficient, proliferation resistant and environmentally sustainable nuclear fuel cycle, providing the maximum benefit to Member States.

Nuclear Fuel Cycle Objectives

In September, the Agency published *Nuclear Fuel Cycle Objectives* (IAEA Nuclear Energy Series No. NF-O). This high level publication sets out the overarching objectives of all Agency activities related to the nuclear fuel cycle.

Uranium Production Cycle and the Environment

Accurate knowledge of uranium resources, production and demand worldwide is essential for planning the supply of uranium fuel for nuclear power plants. The next issue of the joint IAEA–OECD/NEA publication *Uranium 2014: Resources, Production and Demand*, also referred to as the 'Red Book', is expected in 2014. The Agency's public on-line databases offer current information on the topic[1].

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Identifying and extracting uranium resources is a challenge, especially in areas that have not been previously investigated (Fig. 1). To assist Member States, the Agency organized a series of meetings and training courses throughout the year. For example, some 250 experts from 35 countries were trained in uranium geology, exploration, mining and processing in various interregional and regional courses and workshops held in Chile, the Democratic Republic of the Congo, India, Malawi, Tunisia and Zambia. A number of Technical Meetings held in Vienna attracted more than 120 participants. In August, participants in a meeting of the Uranium Mining and Remediation Exchange Group visited uranium mines, both operating and under remediation, in the Czech Republic.

FIG. 1. Excavating an evaluation trench at a uranium deposit in central Jordan.

The availability of unconventional uranium resources is a factor when estimating total uranium resources. These include uranium in seawater and uranium recoverable as a by-product of other extraction processes. Past estimates of potentially recoverable uranium associated with phosphates, non-ferrous ores, carbonatite, black schists or shales, and lignite are of the order of 10 million tonnes of uranium (Mt U). Responding to continued Member State interest in the recovery of uranium from phosphate and other mineral ores, 49 participants from 22 countries were trained at an interregional training course in Tunisia that focused on extraction of uranium from phosphoric acid in a sustainable and cost effective manner.

An Agency technical cooperation project helped Peru demonstrate that, apart from its known deposits of uranium, the country has additional geological terrains favourable to hosting deposits of uranium. The project also provided training to new staff in the geology of uranium.

Thorium has been used as a nuclear fuel on a demonstration basis, although its broader use depends on the commercial deployment of thorium fuelled reactors. Known world thorium resources are estimated to be about 6–7 Mt. At a Technical Meeting in Vienna, participants from 32 countries discussed recent advances in identifying thorium resources that could be obtained as a by-product of rare earth elements mining and processing.

[1] The on-line World Distribution of Uranium Deposits (UDEPO) and World Thorium Deposits and Resources (ThDEPO) databases can be found at: *http://infcis.iaea.org*.

UPSAT Review

Uranium Production Site Appraisal Team (UPSAT) missions are designed to assist Member States in enhancing the operational performance and safety of uranium mining across all phases of the uranium production cycle. In May, the United Republic of Tanzania, a potential 'newcomer' to uranium mining, hosted an UPSAT mission to review its exploration and mining projects. The review focused on the areas of regulatory systems, operations, safety and the environment, social licensing and capacity building. The Mkuju River mining project, one of the projects reviewed by the mission, is located in the Selous Game Reserve and is expected to be the first to start production (2014–2015) (Fig. 2). Feedback from the mission will help improve the code of practice being developed for the uranium industry and may also benefit other countries in Africa, where a number of similar projects are being planned, potentially making the region one of the leading producers of uranium in the near future. This UPSAT mission is one of the many activities implemented through the Agency's technical cooperation programme.

FIG. 2. A geologist from uranium producer Uranium One (second from the left) with UPSAT members on the Mkuju River site, United Republic of Tanzania.

Nuclear Power Reactor Fuel Engineering

The Agency assists Member States in sharing information and undertakes cooperative research on the development, design, manufacture, use and performance of nuclear fuel. Following the completion of a long-running series of CRPs on reactor fuel modelling, the Agency published *Improvement of Computer Codes Used for Fuel Behaviour Simulation (FUMEX-III)* (IAEA-TECDOC-1697), which extends the work of FUMEX-II (Fuel Modelling at Extended Burnup) to cover a wider and more ambitious range of fuel performance parameters.

Some reactor owners have expressed concern over the assurance of a long term supply of reactor fuel. One potential mitigating strategy is to use fuel from more than one supplier. However, due to differences in design and material, use of fuel from different suppliers in the same reactor core can present both technical and regulatory challenges. The Agency published *Operation and Licensing of Mixed Cores in Water Cooled Reactors* (IAEA-TECDOC-1720) to help countries address these issues.

In line with the heightened global focus on the performance of nuclear fuel under accident conditions, the Agency published *Fuel Behaviour and Modelling under Severe Transient and Loss of Coolant Accident (LOCA) Conditions* (IAEA-TECDOC-CD-1709). Capturing the current state of work on fuel behaviour under accident conditions, this publication provides the starting point for a new CRP on this subject.

Spent Fuel Management

Spent fuel storage is an interim step in the back end of the nuclear fuel cycle whose duration is dependent on national policy. For countries opting for reprocessing, the duration can be relatively short. However, countries opting for direct disposal of spent fuel need to store such fuel until geological disposal facilities become available. The first geological disposal facility is expected to be operational in 2022, and it will be several decades until such facilities are commonly available in countries with nuclear power programmes.

To ensure the safety of ongoing spent fuel storage, a good understanding of the processes that may cause deterioration of both the spent fuel and the storage system is needed. In 2013, work to increase understanding of these processes continued through the long standing CRP on Spent Fuel Performance Assessment and Research (SPAR), which held its third Technical Meeting in Busan, Republic of Korea, in November (Fig. 3).

FIG. 3. Participants in the SPAR CRP inspecting the DrySim6 dry storage simulation test equipment at the Korea Atomic Energy Research Institute. (Photograph courtesy of VUJE.)

In addition, a second CRP on Demonstrating Performance of Spent Fuel and Related Storage System Components during Very Long Term Storage (DEMO) was launched to set up a dry storage demonstration test and to address specific issues related to dry storage systems. The first Technical Meeting was held in April in Cordoba, Argentina.

In response to Member State requests, a Technical Meeting on Spent Fuel Storage Options was held in July in Vienna. Participants from 23 countries accounting for more than 90% of the world's spent fuel provided an update on the available technologies for storing spent fuel. Other activities related to spent fuel management focused on implementation of the IAEA Action Plan on Nuclear Safety. In July, the terms of reference for a Spent Fuel Management Network (SFM-Net) were developed. In addition, a new CRP on Management of Severely Damaged Spent Fuel and Corium, aimed at developing and sharing techniques for managing damaged fuel and debris such as that expected during the Fukushima remediation efforts, was approved.

Topical Advanced Fuel Cycles Issues

A major trend in nuclear energy research is the search for long term sustainability in the nuclear fuel cycle, involving the efficient utilization of resources, management of radioactive waste and proliferation resistance. One promising avenue towards such sustainability is the use of advanced nuclear fuel cycles that partition minor actinides from the spent fuel and subsequently transmute these problematic constituents into shorter lived elements. This not only enables the efficient use of resources but also reduces the volume and radiotoxicity of the final waste, mitigating the potential environmental burden. By avoiding separation of pure fissile material, these advanced processes also strengthen proliferation resistance. Many countries with large nuclear installations are exploring these processes for next generation fuel cycles. A Technical Meeting held in Vienna in November that reviewed recent developments in advanced fuel cycles, with an emphasis on recycling technologies, demonstrated the need to coordinate and integrate work being done in the various disciplines in this field.

Another key goal of advanced fuel cycles is to produce more energy from a given amount of natural uranium resources. While fast breeder reactor fuel cycles have the potential to provide a hundred times more energy from uranium resources than is obtained today, the resource utilization of fuel cycles based on thermal reactors can also be improved. Of the currently available thermal reactors, heavy water reactors provide the highest resource utilization. An Agency meeting held in April in Mumbai, India, focused on the efficient use of existing uranium fuel in pressurized heavy water reactors, structure modifications planned in fuel bundle designs and the use of advanced fuels such as thorium, slightly enriched uranium and mixed oxide fuel.

One underutilized resource is the uranium produced from reprocessing operations. An Agency meeting in November allowed participants to share their experience and to discuss interesting prospects for the near future, such as the use of reprocessed uranium in heavy water reactors after blending with depleted uranium to produce either a natural uranium equivalent or uranium with a small residual enrichment.