
Nuclear Science

Objective

To increase Member State capabilities in the development and application of nuclear science as a tool for their technological and economic development. To assist Member States in the management and effective utilization of research reactors.

Nuclear Data

Throughout 2015, the Agency continued to coordinate the International Network of Nuclear Reaction Data Centres (NRDC) and the International Network of Nuclear Structure and Decay Data Evaluators (NSDD) — the two networks that link regional data centres worldwide. In April, it held a Technical Meeting of the NRDC in Vienna, with 16 participants from 10 Member States. During the meeting, two new data centres, in Romania and the United States of America, joined the network, bringing the total to 13 centres in nine countries. During the year, the Agency added over 500 experiments to the Experimental Nuclear Reaction Data (EXFOR) database, the NRDC's main product, which now covers more than 21 000 experiments.

In April, the Agency held a Technical Meeting of the NSDD at its Headquarters in Vienna. The 36 meeting participants from 15 Member States assessed the current status of the Evaluated Nuclear Structure Data File (ENSDF) and drew a road map for updating and maintaining existing nuclear structure codes and developing new ones. The Agency also conducted two training workshops jointly with the Abdus Salam International Centre for Theoretical Physics (ICTP) for 64 participants from 21 Member States. The first workshop, in March, addressed modern plasma spectroscopy methods; the second, held in April, looked at nuclear data for neutron dosimetry and analytical methods for research reactors.

Research Reactors

Utilization and application of research reactors

In November, 314 experts from 56 Member States participated in the International Conference on Research Reactors: Safe Management and Effective Utilization. Held at the Agency's Headquarters in Vienna, the conference provided a forum for the exchange of information and experience on research reactor operation and maintenance, utilization, safety and security, decommissioning, and fuel management, as well as new research reactor projects.

In the first half of 2015, the Agency held an interlaboratory comparison exercise on neutron activation analysis involving 35 facilities. In a follow-up workshop, held in August

in Delft, Netherlands, 32 participants from 28 Member States shared good practices and the lessons learned from the exercise.

To explore and quantify national capabilities to produce molybdenum-99 (^{99}Mo) through neutron capture pathway on natural or ^{98}Mo enriched targets, the Agency carried out a round robin exercise involving teams at 18 research reactors (Fig. 1). Each team performed a set of experiments, and the results were then discussed and analysed during a follow-up workshop, held in December in Vienna, with 17 participants from 17 Member States.



FIG. 1. Metallic (left) and oxide (right) samples of natural molybdenum used in the molybdenum-99 round robin exercise.

The Agency worked with the Korea Atomic Energy Research Institute to organize the 2015 International HANARO Symposium, held jointly with the IAEA Regional Workshop on Research Reactor Coalitions: Enhanced Networking in the Asia-Pacific Region. The symposium, held in May in Daejeon, Republic of Korea, was attended by more than 200 participants from 30 Member States. The participants discussed issues such as research reactor utilization, operation and maintenance, safety, and ageing management.

Through two six week, hands-on training courses on research reactors, organized in cooperation with the Eastern European Research Reactor Initiative (EERRI), the Agency provided training to 18 participants from 8 Member States. The courses were hosted by facilities in Austria, the Czech Republic, Hungary and Slovenia. A total of 86 students from around the world have benefited from the training programme since its inception in 2009.

From 28 September to 2 October, the Agency held the second Training Workshop on Advanced Use of Neutron Imaging for Research and Applications, in Villigen, Switzerland. The workshop was attended by 24 participants and 8 lecturers from 20 Member States and featured hands-on training on neutron and X ray imaging instruments at the Paul Scherrer Institute.

During the year, the Agency issued three publications presenting the outcomes of coordinated research projects (CRPs) on research reactors: *Research Reactor Benchmarking Database: Facility Specification and Experimental Data* (Technical Reports Series No. 480), *Feasibility of Producing Molybdenum-99 on a Small Scale Using Fission of Low Enriched Uranium or Neutron Activation of Natural Molybdenum* (Technical Reports Series No. 478) and *Use of Neutron Beams for Materials Research Relevant to the Nuclear Energy Sector* (IAEA-TECDOC-1773).

New research reactor projects, infrastructure development and capacity building

To assist Member States in planning for a new research reactor within the framework of the Agency's 'Milestones' approach, the Agency held a Training Workshop on Assessment

of the National Nuclear Infrastructure to Support a New Research Reactor Project. The workshop, held in May, was attended by 27 participants from 22 Member States. Also in May, a Training Workshop on Milestones and Infrastructure for New Research Reactor Projects was held in Cairo, Egypt. The workshop was organized in cooperation with the Arab Network of Nuclear Regulators (ANNuR) and the Forum of Nuclear Regulatory Bodies in Africa (FNRBA), and attended by 18 participants from 11 Member States.

In January and March, the Agency conducted two expert missions, to the Sudan and the Plurinational State of Bolivia, respectively. The missions were aimed at assisting those countries in planning the construction of their first research reactors.

To help Member States build capacity, the Agency co-organized the first meetings of the Internet Reactor Laboratory (IRL) projects in Latin America and Europe. The meetings were held in Bariloche, Argentina, in September, in cooperation with the National Atomic Energy Commission (CNEA) of Argentina; and in Saclay, France, in October, in cooperation with the Atomic Energy Commission (CEA). A hands-on training course on research reactors was organized by reactor facilities at Indonesia's National Nuclear Energy Agency (BATAN) and the Malaysian Nuclear Agency. The Agency supported the attendance of 11 participants from seven Member States. Both activities were implemented in the framework of projects funded by the Peaceful Uses Initiative.

During the 59th regular session of the General Conference, the Director General designated the French CEA (Research Centres of Saclay and Cadarache) as the first IAEA designated International Centre based on Research Reactor (ICERR). This designation recognizes an organization's ability to serve as a reference point at the international level in providing research and capacity building services to other organizations and Member States.

Research reactor operation and maintenance

During the year, the Agency organized training and meetings on research reactor operation and maintenance. In April, a meeting on the implications of the Fukushima Daiichi accident for research reactors was held in Tel Aviv, Israel, attended by 29 participants from 10 Member States. At a Training Workshop on Non-Destructive Examination and In-Service Inspection of Research Reactors, held at the Agency's Headquarters in October, 16 participants from 12 Member States received practical training at the TRIGA research reactor at the Institute of Atomic and Subatomic Physics of Vienna Technical University.

In cooperation with the National Organization of Test, Research, and Training Reactors (TRTR) of the United States of America, the Agency organized the joint 2015 TRTR Conference-Technical Meeting on Research Reactor Ageing Management, Refurbishment and Modernization. Held in October in Brewster, MA, the conference attracted 160 participants from 20 countries. Approximately 50 presentations were delivered, covering research reactor operation and maintenance, utilization, research, regulatory aspects and training activities.

Research reactor fuel cycle

Three new CRPs addressing the research reactor fuel cycle were initiated in 2015. In April, work began on a new CRP entitled 'Benchmarks of Computational Tools against Experimental Data on Fuel Burnup and Material Activation for Utilization, Operation and Safety Analysis of Research Reactors', with the participation of 12 Member States. In June, a CRP entitled 'Options and Technologies for Managing the Back End of the Research Reactor Fuel Cycle' was started, with 15 participating Member States. And in December, a new CRP on accelerator driven system (ADS) applications and the use of low enriched uranium (LEU) in ADSs was initiated, with participants from 15 Member States.

The Agency continued its efforts to support medical isotope production without the use of high enriched uranium (HEU). In October, it hosted a Technical Meeting on the Global

Capabilities for the Production and Manufacture of Molybdenum-99 Targets, attended by 31 participants from 15 Member States and the European Union. It also participated in the 2015 ^{99}Mo Topical Meeting, held by the National Nuclear Security Administration of the United States of America; the Fifth Workshop on Signatures of Medical and Industrial Isotope Production (WOSMIP); and the OECD Nuclear Energy Agency High-level Group on the Security of Supply of Medical Radioisotopes.

During the year, the Agency cooperated with the European Nuclear Society in organizing the 19th International Topical Meeting on Research Reactor Fuel Management (RRFM), held in April in Bucharest, Romania, and attended by 211 participants from 31 Member States. The Agency cooperated with Argonne National Laboratory in organizing the 36th Annual International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR), held in October in Seoul, Republic of Korea. The meeting drew 183 participants from 21 Member States.

The Agency continued to support Member State requests to minimize civilian use of HEU. In July, it held a meeting, in cooperation with the National Academy of Sciences of the United States of America, to update a list of operational civilian research reactor facilities that use HEU fuel; 24 participants from five Member States attended. During the year, the Agency provided support for the conversion of the Jamaican Slowpoke reactor to an LEU core, which took place in September.

The Agency continued to support Ghana in its efforts to convert the core of its Miniature Neutron Source Reactor (MNSR) from HEU to LEU fuel and to return the HEU core to China, a step expected to occur in 2016. In February, the Agency received a request for assistance from the Syrian Arab Republic for the conversion of the core of its MNSR from HEU to LEU fuel, and the return of the HEU core to China. In December, representatives of Member States hosting an MNSR, and stakeholders supporting the conversion of MNSR cores from HEU to LEU fuel and the return of HEU to the country of origin, participated in a Technical Meeting on the Conversion of Miniature Neutron Source Reactors, held in Vienna. During the meeting, all Member States with MNSRs confirmed their interest in the conversion of their reactors.

During the year, 26.6 litres of liquid HEU fuel from Uzbekistan (Fig. 2) and 1.9 kilograms of fresh HEU fuel from Georgia was repatriated to the Russian Federation. With the shipments, Uzbekistan and Georgia became free of HEU.

In June, Uzbekistan hosted the Ninth Technical Meeting on Lessons Learned from the Russian Research Reactor Fuel Return (RRRFR) Programme, attended by 81 participants



FIG. 2. A truck carrying a transport canister with irradiated liquid HEU fuel drives into a cargo plane for repatriation of the fuel to the Russian Federation.

from 21 Member States. The event included updates on the repatriation programmes for HEU research reactor fuel originating from China, the Russian Federation and the United States of America.

Accelerator Applications

In view of the growing number of accelerator applications, the Agency hosted a side event entitled ‘Socio-economic Impact of Accelerator-based Research’ at the 59th regular session of the General Conference. During the event, international experts highlighted the unique role of particle accelerators in modifying materials and providing analytical and structural information for research.

In 2015, the Agency launched the Accelerator Knowledge Portal, providing access to a variety of information for accelerator scientists, users and service providers worldwide. The Portal contains details on 200 linear electrostatic accelerators from 49 Member States and on 57 synchrotron light sources from 22 Member States.

The Agency also co-organized the 12th International Topical Meeting on Nuclear Applications of Accelerators (AccApp’15), held in Washington, DC, during the American Nuclear Society (ANS) Winter Meeting. Meeting participants discussed the results of a recently completed CRP entitled ‘Accelerator Simulation and Theoretical Modelling of Radiation Effects (SMoRE)’. The project focused on the use of ion beams to simulate fast neutron damage to candidate fuel cladding and pressure vessel materials for future reactors. The long term stability of a variety of structural alloys and other materials was studied, along with their mechanical properties, microstructural changes and irradiation resistance. The CRP resulted in several advances in multiscale modelling of radiation effects, especially in the area of iron-chromium and oxide dispersion strengthened (ODS) alloys.

Synchrotron applications

The IAEA–Elettra Sincrotrone Trieste joint experimental facility provides access to synchrotron radiation for Member States, enabling them to carry out experiments for environmental and industrial applications. During 2015, 16 research groups from 14 Member States utilized 159 beam-time shifts (53 days). The groups also made use of the analytical capabilities of the Agency’s multipurpose X ray spectrometry at the X ray fluorescence beam line. The results obtained indicate potential for its use in analysis of a variety of materials.

In 2015, the Agency entered into a cooperation agreement for the First African Light Source Conference and Workshop. The aim is to bring the first synchrotron to Africa, the only continent without one.

Materials modification and analysis with accelerator-based techniques

Focused megaelectronvolt ion beams are ideal tools for investigating the effects of radiation induced displacement damage on the electronic performance of semiconductor devices. Participants in the recently completed CRP entitled ‘Utilization of Ion Accelerators for Studying and Modelling of Radiation Induced Defects in Semiconductors and Insulators’ developed a theoretical model and a corresponding experimental protocol to establish a methodology to characterize the radiation damage of a semiconductor and insulator materials as an irradiation-independent physical value.

To discuss the possible effects of radiation on heritage objects during ion and photon beam experiments, and to suggest safer procedures and improved practices for monitoring and mitigation strategies, the Agency held a Technical Meeting in the Palais de Louvre in

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France, co-organized by the Centre for Research and Restoration of the Museums of France (C2RMF) and the French laboratory IPANEMA. The event was unique in providing a common platform for physicists, chemists, materials scientists, archaeologists, conservators and curators.

Nuclear Instrumentation

Through scientific visits to, and fellowships and internships at, its Nuclear Science and Instrumentation Laboratory in Seibersdorf, as well as training sessions in Member States, the Agency provided 32 young experts from 17 Member States with training in areas ranging from signal processing to hardware interfacing and data acquisition and analysis.

During the year, the Agency also began testing a system to enable rapid environmental mapping of radioactivity using unmanned aerial vehicles, developed in the wake of the accident at the Fukushima Daiichi nuclear power plant. The new system, which is based on radiation detectors and sensor packages mounted on a customized hexacopter, was created in collaboration with Fukushima Prefecture.

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Nuclear Fusion

In the area of nuclear fusion, the Agency worked to consolidate design choices and technologies for ITER — a project to demonstrate self-sustained fusion energy generation in excess of 500 MW — and to close the gaps between ITER and a demonstration fusion plant at industrial scale (Fig. 3). Around 650 experts from 30 Member States addressed various physics and technology issues in 12 Technical Meetings and workshops conducted in 2015. A side event on fusion held during the General Conference summarized the status of fusion research around the world. Also during the year, the Agency organized the third Demonstration Fusion Power Plant (DEMO) Programme Workshop. This year’s workshop, held in May, was hosted by the Institute of Plasma Physics of the Chinese Academy of Sciences, Hefei, China.



FIG. 3. Aerial view of ITER site as of September 2015.