

Nuclear Power, Fuel Cycle and Nuclear Science

over 650  **on-line training and education courses** hosted on **CLP4NET**

33

coordinated research projects



4

Nuclear Knowledge Management Schools

6

Nuclear Energy Management Schools

33



Integrated Nuclear Infrastructure Training activities

INPRO

international collaborative projects



15

completed

5

ongoing



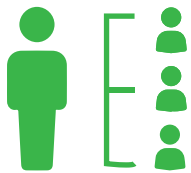
publications

Internet Reactor Laboratory

4 host institutions



9 guest institutions



18

professional networks

8

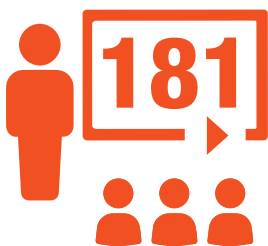
missions



5

IAEA-designated International Centres based on Research Reactors

in **5** countries



consultancy meetings



74 technical meetings

Nuclear Science

Objective

To support Member States in strengthening capabilities in the development and application of nuclear science as a tool for their technological and economic development. To assist Member States in enhancing sustainable operation, including effective utilization of research reactors, in implementing new research reactor projects and nuclear capacity building programmes, based on access to research reactors.

Nuclear Data

The Agency released a new neutron metrology library called the International Reactor Dosimetry and Fusion File (IRDFF-II) that supports a broad range of applications — from lifetime management and assessment of nuclear power plants to boron neutron capture therapy, use of medical isotopes, nuclear physics measurements and reactor safety applications. The library includes 119 neutron metrology reactions, for which high quality cross-section data and uncertainties were evaluated.

A new photonuclear data library featuring high quality data for 219 nuclides is one of the main products of a CRP on photon strength functions and photonuclear reactions. The project participants used modern nuclear reaction software, such as the TALYS and CoH3 nuclear model codes, to better describe relevant cross-sections, allowing reactor and Monte Carlo transport software to provide improved estimates on issues such as radiation shielding and transmutation of radioactive waste. Reduced uncertainty margins will allow Member States to make better predictions of isotopic yields during irradiation.

Research Reactors

Utilization and applications of research reactors

The Agency supported interlaboratory proficiency testing of 49 neutron activation analysis laboratories in 36 Member States. The first major update of a neutron activation analysis e-learning course was completed with the development of ten new modules.

Two expert missions to assist Member States with planning were undertaken, to Saudi Arabia and Morocco. E-learning modules for a course entitled 'Strategic Planning for National Nuclear Institutions' were finalized, and two e-learning courses were developed on nuclear analytical techniques for forensic science and introductory training for research reactor personnel, the latter of which is available in both English and Spanish.

The Agency published *Benchmarking against Experimental Data of Neutronics and Thermohydraulic Computational Methods and Tools for Operation and Safety Analysis of Research Reactors* (IAEA-TECDOC-1879), presenting results of a CRP.

Integrated Research Reactor Utilization Review (IRRUR) missions were approved as an official Agency peer review service based on the feedback from a pilot IRRUR mission conducted to the TRIGA research reactor in Italy. These missions provide an assessment of the utilization of a research reactor and identify further utilization areas, research and development, as well as products and services that the research reactor can provide.

New research reactor projects, infrastructure development and capacity building

A Regional Research Reactor School on reactor physics and neutron applications was conducted in Japan for countries in the Asia and the Pacific region and in Africa, aimed at building nuclear competence in those countries. A national workshop on the Milestones Approach for a research reactor programme was conducted in Senegal. Preparations for a future Integrated Nuclear Infrastructure Review for Research Reactors mission were also discussed during the workshop.

Research reactor fuel cycle

Member States are working towards minimizing high enriched uranium (HEU) in civilian use through programmes to reduce enrichment for research and test reactors, and through take-back programmes that return HEU to the countries of origin. The Agency received a request from Kazakhstan for assistance in HEU minimization, for removal of spent HEU from the IVG.1M reactor to the Russian Federation and disposition of HEU from the IGR reactor in Kazakhstan. The Agency initiated procurement of the services for the preparatory work for the return of IVG.1M reactor HEU fuel to the Russian Federation.

Practical Arrangements on cooperation between the Agency and the Sosny Joint Institute for Power and Nuclear Research in Belarus were signed, focused on the use of the institute's critical facilities to characterize advanced reactor fuels, provide benchmarking experiments, study the safety of fuel assemblies, and provide education and training.

Several meetings and workshops focused on improving Member State use and understanding of best practices for research reactors. The Agency organized a Technical Meeting on the Current State of and Developments in the Management of Radioactive Waste from Research Reactors. A Meeting on Lessons Learned from Miniature Neutron Source Reactor (MNSR) Conversion Projects, organized by the Agency and the China Nuclear Energy Industry Corporation, was held in China. A Training Workshop on the Use of Decision Support Tools for Research Reactor Spent Fuel Management was conducted in Vienna. A Technical Meeting on Computational Benchmarks for Research Reactor Fuel Burnup and Activation Codes was conducted in Vienna to review the results of the computational benchmarks that were completed under a related CRP.

Research reactor operation and maintenance

The Agency organized a number of technical meetings and workshops relating to the operation and maintenance of research reactors. At a Technical Meeting on Risk Informed In-Service Inspection and Decision Making for Research Reactors held in Vienna, participants reviewed the current status and practices, and the formulation of the scope and methodology of a CRP on this topic. Participants in a Training Workshop on Integrated Management Systems for Research Reactors and Good Practices, held in Vienna, exchanged knowledge and experiences in the implementation of integrated management systems in research reactors. A Technical Meeting on Digital Instrumentation and Control Systems for Upgrades and New Research Reactors was conducted in Vienna to enable the exchange of information and experiences relating to the technical and managerial aspects of research reactor projects involving the modernization of digital instrumentation and control systems.

A Workshop on Simulation of a Non-Power Reactor for Training Purposes was held in Argentina, in cooperation with the Government of Argentina, to transfer experience in the field of operation and performance analysis of research reactors to contribute to increased technical competence and sustainable development of nuclear technology.

A support mission was conducted to the Democratic Republic of the Congo for non-destructive examination and in-service inspection. During this mission, 75 fuel elements of the TRICO II research reactor were inspected using an underwater radiation resistant camera supplied by the Agency.

Different types of Operation and Maintenance Assessment for Research Reactors (OMARR) missions were conducted to Indonesia, Thailand and Uzbekistan to provide advice and assistance towards improving the performance of research reactors. The main mission for the Indonesian facility was conducted in October and resulted in recommendations for the preparation of an action plan to extend operation of the reactor with enhanced availability and reliability for another 15–20 years. An OMARR follow-up mission to research reactor WWR-SM in Uzbekistan was conducted and the operator was advised on a further plan of action for its continued long term operation.

The Agency published *Material Properties Database for Irradiated Core Structural Components for Lifetime Management for Long Term Operation of Research Reactors* (IAEA-TECDOC-1871), which presents the results of a CRP on the topic. The information provided can be used to support the safe and reliable long term operation of existing research reactors and the design of new research reactors.

Accelerator Technologies and Their Applications

The Accelerator Knowledge Portal updated five of its existing research infrastructures and added one new infrastructure. These updates included electrostatic accelerators, synchrotron light sources, neutron spallation sources, neutron scattering instruments, X ray free electron lasers and the new medical cyclotrons infrastructure. The portal now totals more than 1700 facilities. More than 7000 users from 83 Member States visited the portal, twice as many as in 2018.

The Agency publication *Improvement of the Reliability and Accuracy of Heavy Ion Beam Analysis* (Technical Reports Series No. 485) highlights the achievements of a CRP that addressed limitations in the use of heavy ions as an analytical tool. The extensive database of the new stopping cross-sections included in the publication contains new data which will significantly benefit the ion beam community, leading to improved accuracy of quantitative light element analysis worldwide.

A new Partnership Agreement with Elettra Sincrotrone Trieste, Italy, enabled 23 experiments by users from 11 Member States at the X ray fluorescence beam line. The first Joint IAEA–Elettra Sincrotrone Trieste training workshop in synchrotron light experiments was also organized (Fig. 1). Through an existing Partnership Agreement with the Ruđer Bošković Institute, Zagreb, 17 experiments involving 5 Member States were performed at their ion beam. Furthermore, a training workshop for specialists from accelerator facilities was organized.

Upon request, targeted support through expert missions was provided to small accelerator facilities in Bangladesh, Croatia and Greece. As a result, these accelerator facilities were back to operation, their performance was improved or specific recommendations were provided on how to ensure sustainable operation in the future.

Several events were organized over the year; highlights included the Joint ICTP–IAEA Advanced Workshop on Enhancing Accelerator-Based Analytical Techniques for Forensic Science for both analysts and forensic end users, held in Trieste, Italy; a Technical Meeting on Non-spallation Accelerator-based Production of Neutrons, held in Vienna, which culminated in a review of the applications of a variety of accelerator technologies, target

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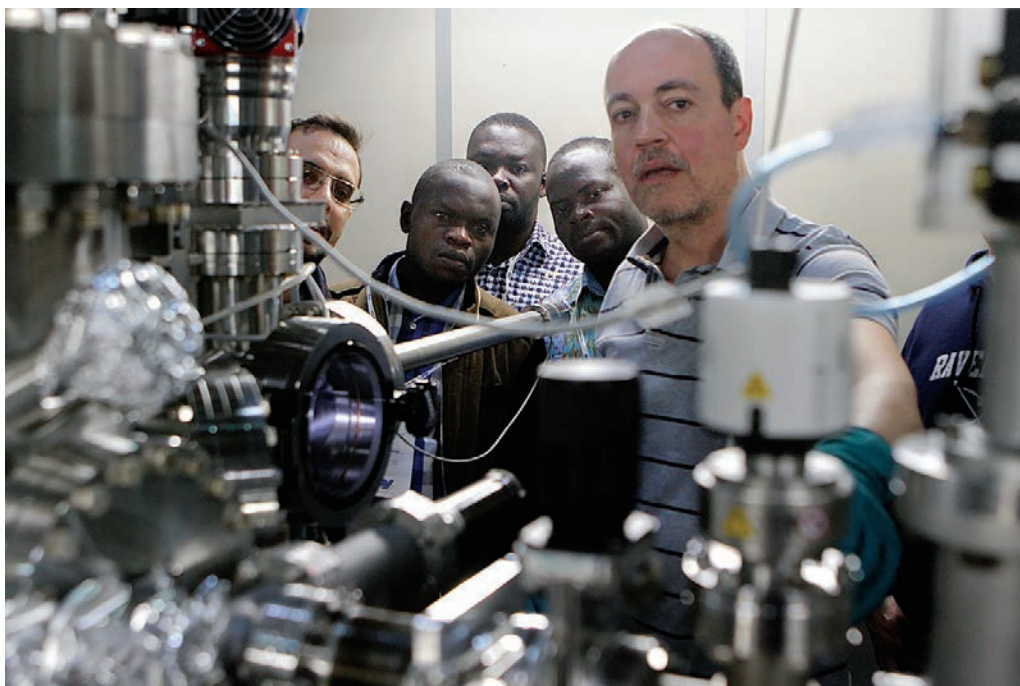


FIG. 1. Participants in an Agency training workshop observe a demonstration of the instrumentation installed at the joint Agency–Elettra X ray fluorescence beam line in Trieste, Italy. (Photograph courtesy of Elettra.)

designs for neutron production and practical aspects of planning and establishment of such facilities, including the required infrastructure, training of personnel, facility cost estimates, licensing safety and security issues; and a Workshop on Financial and Economic Feasibility Analysis for Nuclear and Radiation Technology Projects aimed at facilitating self-reliance and sustainability of national nuclear institutions. This latter workshop introduced and demonstrated the use of the United Nations Industrial Development Organization's Computer Model for Feasibility Analysis and Reporting (COMFAR) and the Agency's Extended Input Output Model for Nuclear Power Plant Impact Assessment (EMPOWER) for modelling macroeconomic effects of projects such as medical cyclotrons and gamma irradiators.

Nuclear Instrumentation

The Nuclear Science and Instrumentation Laboratory in Seibersdorf, Austria, reached several important milestones in establishing a Neutron Science Facility: arrival of a deuterium–tritium based neutron generator; establishment of building refurbishment work requirements; completion of preliminary shielding calculations; installation of a detection system for neutron activation analysis; commissioning of a neutron/gamma radiation monitoring system; and installation and testing of a neutron and X ray imaging system (Fig. 2).

Several workshops and training courses relating to human capacity building in nuclear instrumentation were held during the year. These included a Training Workshop on In Situ Characterisation of Contaminated Sites, held in Pécs, Hungary, in cooperation with the National Food Chain Safety Directorate of Hungary (Fig. 3); a Joint ICTP–IAEA Advanced Workshop on Portable X-Ray Spectrometry Techniques for Characterization of Valuable Archaeological/Art Objects, in Trieste, Italy; a regional training course on radiotracer and sealed source methodology and technology as applied to industry and the environment, in Seibersdorf; an eight week group fellowship training course on X ray fluorescence based analytical techniques and applications, in Seibersdorf; and group fellowship training on

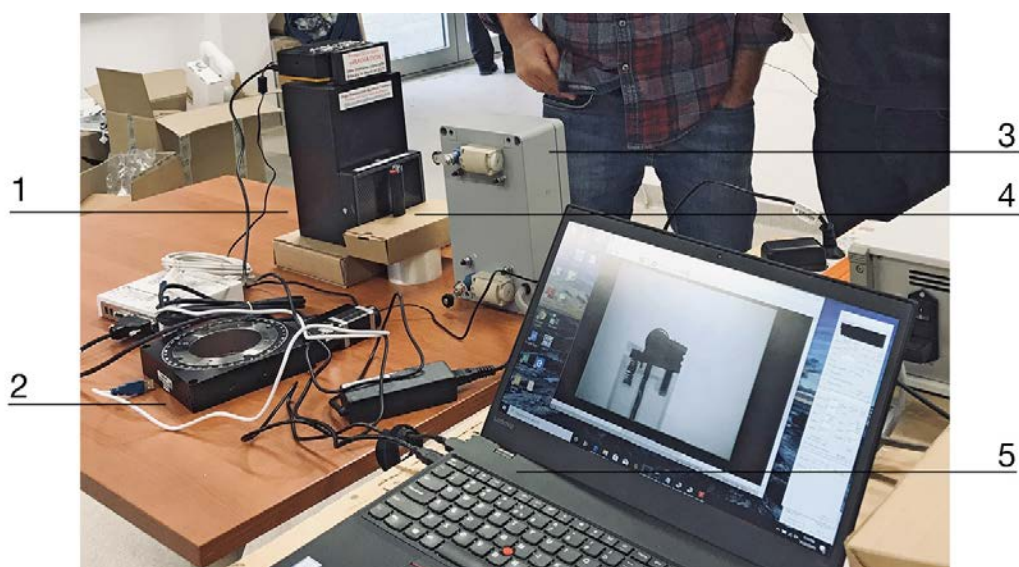


FIG. 2. Testing of the dual neutron/X ray imaging system: (1) camera box; (2) rotating stage (not in use in this image); (3) X ray source; (4) sample; (5) computer control.

nuclear instrumentation at the Birine Nuclear Research Centre in Algeria. The group fellowship events resulted in training for 20 young researchers from 14 Member States.

The Agency provided support to the Fukushima Prefectural Centre for Environmental Creation in Japan in the area of calibration of instrumentation, data collection strategies and interpretation of results for radiological mapping of four different sites. In addition, one member of the Centre’s team was trained at the Agency’s Seibersdorf laboratories on operation, use and calibration of various instruments; activity to dose rate conversion methodologies; Monte Carlo modelling; use of R code for radiological mapping; and hands-on training for drone flying.



FIG. 3. Trainees equipped with gamma spectrometers and navigation systems undertake field measurements at a former uranium mine in Pécs, Hungary.

Nuclear Fusion

The sixth Demonstration Fusion Power Plant (DEMO) Programme Workshop was held in Moscow. Discussions and information exchange at this year's workshop focused on issues and challenges relating to plasma stability, materials science and the impact of the operational conditions of DEMO.

Over the year, several technical meetings were organized on topics relating to fusion reactors, energetic particle research and plasma physics, including the 12th IAEA Technical Meeting on Control, Data Acquisition and Remote Participation for Fusion Research, held in Daejeon, Republic of Korea; the 16th Technical Meeting on Energetic Particles in Magnetic Confinement Systems – Theory of Plasma Instabilities, in Shizuoka, Japan; and the third Technical Meeting on Divertor Concepts, in Vienna.

A new Agency publication, *Conceptual Development of Steady State Compact Fusion Neutron Sources* (IAEA-TECDOC-1875), highlights the main results and findings of a CRP on the development of conceptual designs for both low and high power compact fusion neutron sources, covering their practical applications and addressing aspects of facility utilization, operation, safety and technology integration.

Support for the Abdus Salam International Centre for Theoretical Physics (ICTP)

The Agency continued to support the ICTP with the aim of enabling young scientists from developing Member States to study, train and build networks in the areas of theoretical physics and applied sciences. A total of 13 co-funded joint events, attended by over 250 participants, were held on topics ranging from medical diagnostic radiology to plasma physics.