Nuclear Sciences and Applications

Applying 21st Century Nuclear Science to 21st Century Problems

Integrating Nuclear Techniques for Development

By enhancing the integration across various thematic areas, the IAEA plays a role in helping to address today’s emerging challenges. In radiation medicine, for example, nuclear technology is used for the diagnosis and treatment of major non-communicable diseases such as cancer and cardiovascular disorders. The Human Health Campus at http://humanhealth.iaea.org provides on-line resources and learning for health professionals working in radiation medicine. Responding to the world cancer crisis, the IAEA developed a unique initiative, the Programme of Action for Cancer Therapy which works closely with the World Health Organization (WHO) through the WHO-IAEA Joint Programme on Cancer Control. The programme aims at providing assistance to Member States to adopt comprehensive national cancer control programmes that encompass early detection, prevention, cancer diagnosis and treatment and palliative care.

In a joint division with the Food and Agriculture Organization of the United Nations, the IAEA assists Member States in applying nuclear techniques to alleviate challenges in food safety, food security and sustainable agricultural development. The IAEA has made significant contributions to helping developing countries adopt sterile insect techniques to suppress and eradicate insect pests that pose a threat to human and to animal health.

Using scientific methods based on the tracing of isotopes, the IAEA is improving the management of the world’s freshwater resources, a key aspect of sustainable development in the face of climate change. The IAEA also helps Member States monitor known sites of radioactive contamination, as manifested by their ongoing efforts in Japan after the incident at Fukushima.

Radioisotope products and radiation technology are essential components for applications across all fields, be it medicine, industry, or agriculture. The demand for the most used radioisotopes has been steadily increasing, such as, for example, fission produced ⁹⁰Mo and ⁹⁹mTc, used for more than 30 million medical procedures worldwide per year. As a result, many countries seek support from the IAEA in integrating these technologies into their development plans, which include strengthening quality assurance practices and regulatory compliances as well as facilitating human resources development.
The IAEA laboratories for nuclear sciences and applications—a unique facility in the United Nations system—provide reference material, quality control and quality assurance services and training courses to Member States, while also setting international standards and conducting ground breaking R&D in a variety of developmental and environmental issues.

Harnessing the power of nuclear science helps countries around the world to address issues such as food security, climate change, water resource scarcity and the looming cancer epidemic in the developing world. By sharing nuclear data, resources and expertise, the IAEA contributes to the capacity building of its Member States and promotes the peaceful uses of nuclear sciences and applications to address basic human development needs.”

Daud Mohamad
Deputy Director General
Department of Nuclear Sciences and Applications

The continuing widespread adoption of radiation and nuclear techniques for non-energy applications is a major driver of the IAEA’s continued involvement in strengthening nuclear science capabilities in Member States. The adoption and use of credible atomic and nuclear data are crucial, as such data provide accurate descriptions of the underlying processes that are harnessed in both energy and non-energy studies, including nuclear fusion, medicine and environmental monitoring. To encourage the use of peaceful nuclear techniques, the IAEA serves as the central agency for the collection and dissemination of data worldwide.

Working as a Part of the Global Community

Contributing to the Millennium Development Goals, the IAEA’s role is to accelerate and enlarge the contribution of nuclear science and technology to global peace, health and prosperity. This requires the sustainable cooperation of Member States, intergovernmental and non-profit organizations, educational and research institutes and laboratories in a variety of fields.

The IAEA works alongside a long list of IAEA collaborating centres, which contribute their own research, training and facilities, and has developed coordinated research activities with experts around the world across various fields related to nuclear science and technology. The training offered by the IAEA sets a high standard for procedures and practices, improves the use of technologies and ensures the reliability of data generated by national and regional laboratories.

The establishment and maintenance of a sound infrastructure in nuclear science is essential to capacity building in a wide range of applications, from health care and agriculture to industry and the environment. By offering training and promoting the transfer of technology, techniques, knowledge, data and expertise in nuclear sciences, the IAEA, through its technical cooperation programme, offers developing Member States a means of achieving sustainable development objectives.

The technical expertise and multilateral mandate of the IAEA allows its many collaborating centres and laboratories around the world to deliver the benefits of nuclear technologies and maximize their sustainability. Given the growing emphasis on utilizing existing capabilities and expanding the use of networks for programme delivery, the collaboration across fields and between the many Member States is likely to grow in the years to come.
Nuclear Sciences and Applications Laboratories

Supporting Development: R&D, Capacity Building and Technical Services

The system of twelve dedicated IAEA laboratory facilities is a unique feature in the United Nations. The laboratories support and implement programmatic activities that respond to the developmental needs of Member States in food and agriculture, human health, environmental monitoring and assessment, as well as the use of nuclear analytical instruments.

The laboratories carry out three essential types of activity, which are simultaneously supported worldwide in Member State laboratories: (i) applied research and development; (ii) training and capacity building and (iii) technical and analytical services. Their primary aim is to assist in increasing the impact of related IAEA programmes.

While the laboratories share certain types of activity, their fields of expertise range from food and agriculture, medical dosimetry to the environment and water resources.

Most of the laboratories are based in Seibersdorf, a town about 35 km southeast of Vienna. There are five FAO-IAEA agriculture and biotechnology laboratories assisting Member States to develop and adapt new and existing agricultural technologies involving isotopes and radiation to suit local requirements and environmental conditions, and to provide the necessary training and analytical services pertaining to the efficient use of these technologies:

- **Insect Pest Control Laboratory:** Develops environmentally friendly methods of pest control (e.g. sterile insect technique, F1-sterility) for area wide control of key pests.

- **Animal Production and Health Laboratory:** Strengthens the productivity of indigenous and exotic livestock breeds through genetic characterization and disease diagnosis.

- **Soil and Water Management and Crop Nutrition Laboratory:** Develops methodologies for the cost effective optimization of water and fertilizer usage.
• **Plant Breeding and Genetics Laboratory:** Focuses on radiation induction and ‘fingerprinting’ of novel plant varieties with improved yield and hardiness under local conditions, such as disease resistance and salinity tolerance.

• **Food and Environmental Protection Laboratory:** Facilitates compliance with regulatory guidelines for international markets through provision of methodologies for determining veterinary drug and pesticide residues.

The **Dosimetry Laboratory**, based in Seibersdorf, is part of the IAEA’s human health programme. It is responsible for the quality assurance aspects of the use of radiation in medicine, it provides dosimetry calibrations for national standards laboratories and conducts audits of the dose in radiotherapy and radiation protection.

From its facility in Seibersdorf, the **Nuclear Spectrometry and Applications Laboratory**, as part of the IAEA's nuclear science programme, works with laboratories in Member States to enhance their use of nuclear instrumentation and nuclear spectrometry based analytical techniques in environmental pollution monitoring and other applications, including nuclear energy systems related needs.

The **Terrestrial Environment Laboratory** facility in Seibersdorf is part of the IAEA’s environment laboratories. Its role is to foster the capabilities of Member States in understanding and protecting the terrestrial environment. To achieve this, the laboratory develops suitable radiological assessment strategies and ensures the quality of measurement results by recommending methods, providing reference materials and organizing proficiency tests.

There are three marine environment laboratories located in Monaco, also part of the IAEA environmental laboratories, dedicated to the preservation of a healthy marine environment and the sustainable development of environmental resources:

• **Radiometrics Laboratory:** An internationally recognized centre for the study of the oceans by use of radionuclides and isotopes as environmental tracers, in collaboration with leading research centres around the world. It develops analytical methods and supports Member States in their quality assurance activities by enabling interlaboratory comparisons and production of reference materials of marine origin.

• **Radioecology Laboratory:** Focuses on the study of nuclear and non-nuclear contaminants in seafood and food webs using radiotracer techniques, on the impact of ocean acidification on the development and biology of marine organisms of commercial interest and on the tracking of carbon export from the upper ocean using natural radiotracers.

• **Marine Environmental Studies Laboratory:** Covers isotopic and elemental analysis of trace elements, organic contaminants and lipid biomarkers. It supports capacity building in Member States to enhance the quality of analytical measurements and the capabilities for marine environmental surveys.

In Vienna, the **Isotope Hydrology Laboratory**, as part of the IAEA’s water resources programme, plays a substantial role in the dissemination of knowledge about state of the art analytical techniques in isotope hydrology.

Training and capacity building is an essential part of technology transfer and is frequently provided at the IAEA laboratories or in regional laboratories. Dozens of training courses, workshops and seminars are held annually at the Nuclear Applications Laboratories, involving hundreds of trainees, with the overall goal of building the capacity of Member States. IAEA fellowships usually extend no more than six months, and while importance is given to training in technology, every effort is made to ensure that equal emphasis is given to the wider aspects of the problem to be studied or solved.

For example, in the courses, trainees learn not only nuclear techniques but also conventional techniques so that they recognize the links. They receive intensive hands-on experience in laboratory analysis and also undertake field work. Most training also includes “training the trainer” elements, so the training will have a multiplier effect. Regional and interregional training courses are held periodically to train young scientists from developing countries in the technologies associated with the application.

Another important function of the IAEA laboratories is the technical and analytical support provided to Member States through evaluation, standardization and selection of appropriate equipment for each specific project or need. Equipment supplied is most effectively used when it is simple, robust, easily repaired and fits well within the local infrastructure and conditions. This is why technical staff, scientists and fellows who are responsible for implementing the projects aim to acquire experience in the routine operation, maintenance and even repair of commonly used equipment. Supplies of frequently required spare parts also can be purchased in bulk and held for quick dispatch to field projects when required.
Coordinated Research Activities
Uniting the World Through Research

The IAEA’s programme of coordinated research activities has been designed to stimulate and coordinate the undertaking of research in selected nuclear fields by scientists in IAEA Member States. The programme brings together scientists in research institutes in both developing and developed IAEA and FAO Member States to collaborate on research topics of common interest. Research, technical and doctoral contracts and cost free research agreements are awarded to Member State institutes for completion of designated research work. For each contract or agreement, one institute staff member is designated as the chief scientific investigator responsible for the progress of the research work. Preference is given to younger and to female researchers.

Through contracts and agreements with institutes in Member States, the coordinated research projects (CRPs) are implemented. Each CRP is a network of 10 to 15 institutes that work in coordination towards achieving the research objectives set by the design of the CRP. The research is conducted at the participating institutes identified in the research contracts and agreements of the CRP. The IAEA acts as the sponsoring and coordinating body whereby an IAEA staff member—or project officer—is assigned to lead each CRP, which normally lasts between 3 and 5 years. A few years ago, a new type of CRP, called a ‘doctoral CRP,’ was introduced whereby PhD students in developing countries are paired with professors in developed country research institutions.

The research encourages the acquisition and dissemination of new knowledge and technology generated through the use of nuclear technologies and isotopic techniques in the various fields of work covered by the IAEA’s mandate. The majority of CRP topics are concentrated in the areas of nuclear sciences and applications in agriculture, human health, industry, hydrology and terrestrial and marine environments. However, CRPs related to nuclear energy and economic studies, waste technology, radiation and radioactive waste safety and nuclear security are also covered by the programme.

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The programme continued to evolve over the years and has handled a budget equaling to over € 150 million since its inception. The chart below illustrates the increase in the budget in 10-year periods.

Quick Facts

In 2010
 106 Member States participated in the programme of coordinated research activities

More than 1500 active contracts and agreements under 125 active CRPs

€ 6000 was the average IAEA contribution per contract per year

80 research coordination meetings held

The idea for coordinated research activities came about in 1957, shortly after the establishment of the IAEA and its subsequent focus on studies in the field of radioactive waste disposal. By arranging for researchers in developing and developed countries to communicate and exchange information and expertise freely, these coordinated research activities would allow multiple countries to collaborate towards achieving a common goal.

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Transferring Results Across Borders

Conservation agriculture aims at improving the livelihoods of farmers through the application of three principles: (i) minimal soil disturbance, (ii) permanent soil cover and (iii) crop rotation.

One recently completed CRP on Integrated Soil, Water and Nutrient Management in Conservation Agriculture, in which unique nuclear techniques utilizing the stable isotopes $^{15}$N and $^{13}$C were used, has provided new and useful scientific data and knowledge.

The information demonstrated that conservation agriculture can benefit Africa, Asia and Latin America by creating higher crop yields through increased soil moisture retention, enhanced biological nitrogen fixation, retention of soil nitrogen and soil carbon sequestration. In addition, conservation agriculture has been shown to help enhance nutrient and water use efficiency.

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The Founding of Coordinated Research Activities
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Nuclear Sciences and Applications Collaborating Centres
Establishing a Culture of Cooperation

As a large international organization with a variety of programmes, initiatives and laboratories, one of the mandates of the IAEA is to promote the peaceful use of nuclear techniques worldwide while also collaborating with other institutions in its Member States in order to implement part of its approved activities. In this regard, the IAEA designates selected institutions as official IAEA collaborating centres (IAEA-CCs). Recognizing the need to preserve and transfer nuclear knowledge, the IAEA-CCs are dedicated to furthering the research, development and training in peaceful applications of nuclear science and technology. By working alongside various nuclear related institutions from around the world, the IAEA contributes to reaching important targets laid out by the United Nations Millennium Development Goals.

The IAEA-CCs are, in general, scientific institutions such as laboratories, universities, research facilities, etc., that receive public recognition by the IAEA and have been designated to collaborate with the IAEA in a variety of fields, such as food safety, environmental protection, water resources and human health. In line with the objectives of the IAEA, IAEA-CCs are expected to further the research, development and training in the peaceful applications of nuclear science and technology.

Through these research and academic institutions, Member States can assist the IAEA with their own original research, development and training in nuclear technologies. As a cooperative mechanism, the IAEA-CC is also efficient, as it encourages centres to share resources, knowledge and expertise.

One of the goals of the IAEA-CC is also to help developing Member States expand their capabilities in these areas and thus improve the quality of life of their citizens. So far, the IAEA-CC has led to socioeconomic benefits in many parts of the world, from Asia to Latin America.

Quick Facts

There are more than 20 IAEA-CCs worldwide in both developed and developing countries.

In addition to a single institution, a department or laboratory within an institution may also be designated as a collaborating centre.

Official selection of an IAEA-CC depends on a variety of criteria, including their adherence to nuclear safety and security guidelines, and a proven record of collaboration with the IAEA.
Fostering Human Nutrition in India and Worldwide

The IAEA formalized its relationship with the St. John’s Research Institute (SJRI) in Bangalore, India, by designating it an IAEA-CC in May 2010. The SJRI has been working with the IAEA’s Nutrition and Health Related Environmental Studies Section since 1988 and is well networked, both in India and internationally. The SJRI was the first collaborating centre designated by the IAEA in the field of human nutrition. Its research also focuses on cancer, infectious diseases and lifestyle related diseases.

The longstanding relationship between the IAEA and SJRI has allowed them to collaborate on a variety of levels. For example, the SJRI analyses samples for Asian and African Member States, provides lecturers for the IAEA’s courses on stable isotope techniques and trains research fellows from Member States worldwide.

Protecting Marine Life with Nuclear Techniques

The Philippine Nuclear Research Institute (PNRI), which is the only IAEA-CC on harmful algal blooms in the world, undertakes research jointly with the IAEA environment laboratories in Monaco to track the impacts and fate of biotoxins in the marine food chain using radiolabelled analogues. Recently, the PNRI undertook studies in Manila Bay to assess the transfer of paralytic shellfish poisoning toxins from harmful algae to green mussels farmed in that area. In addition, a field test based on the use of radiolabelled toxins is currently under development at the PNRI to facilitate the monitoring of aquaculture products.

Sharing Accelerator based Analytics with the Global Community

In 2010, the IAEA added El Centro Nacional de Aceleradores in Seville, Spain, to its list of collaborating centres for its outstanding research activities in accelerator based analytical techniques. During the four year work plan, the two organizations will work on a common project studying long lived radionuclides in marine samples in order to provide Member States with state of the art accelerator based science.

Eradicating Fruit Flies to Facilitate Trade

The IAEA-CC for the Development and Application of the Sterile Insect Technique for Fruit Fly Area Wide Integrated Pest Management in Southern Mexico and Guatemala is a recent addition to the IAEA-CC scheme. The initial goal of the project is to reduce both horticultural losses and insecticide use while also facilitating more international trade in fruits and vegetables. The programme provides training for entomologists and plant protection officials from the entire region. It also develops and validates new methodologies that complement the research done by the IAEA. Thanks to this method, both the Mediterranean and Mexican fruit flies have been almost completely eradicated in Mexico.
The IAEA has a long history of cooperation with other international organizations, regional agencies, non-governmental organizations (NGOs), local and national governments, research and academic institutions. These cooperative efforts make it possible for the IAEA to implement many of its projects undertaken in the area of nuclear applications for peaceful purposes.

Conserving the Earth’s Oceans

The Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO/IOC), the IAEA and the United Nations Environment Programme (UNEP) have pooled their resources to facilitate capacity building in Member States in order to improve their ability to assess, manage and protect marine environments, including oceans, semi-enclosed seas and coastal zones. More specifically, their joint efforts assist Member States to:

- Develop capacities to conduct coastal and marine environmental assessments;
- Improve national and regional capacity to monitor and manage harmful algal events and eutrophication of coastal waters due to nutrient overenrichment;
- Support and promote the Global Partnership on Nutrient Management to address nutrient management challenges;
- Improve capacities to identify sources and sinks of carbon in coastal and oceanic waters and ecosystems;
- Train scientists from Member States in experimental and observational techniques to study ocean acidification, harmful algal blooms and eutrophication and their impacts on coastal and marine biodiversity.

For nearly 50 years, the ICTP has been ensuring that scientists from the developing world have access to the same resources and opportunities enjoyed by their wealthier counterparts. The ICTP is a focal point of cooperation between developed and developing countries, and it has been a major force in countering the scientific brain drain from the developing world.
Alleviating the Cancer Epidemic

Through its Programme of Action for Cancer Therapy, the IAEA has sought to forge partnerships with international organizations, national cancer institutes, NGOs and private companies, in order to fight cancer in the developing world. These partnerships help Member States to develop their national plans for cancer prevention and control and to raise funds to improve conditions and outcomes for cancer patients. As a result, limited resources can be used in the most cost effective way and millions of unnecessary deaths may be prevented. IAEA partnerships also contribute to the global effort to include cancer and other non-communicable diseases within the framework of the Millennium Development Goals.

In light of growing international concern for the global cancer epidemic and its projected increase, in July 2009 the World Health Organization (WHO) and the IAEA launched a Joint Programme on Cancer Control to strengthen and accelerate efforts to fight cancer in the developing world. The WHO’s National Cancer Control Programme seeks to address cancer control through a public health approach and within the context of non-communicable diseases. The National Cancer Control Programme includes the equitable implementation of evidence based interventions for prevention, early detection, diagnosis and treatment and palliative care. The IAEA, with its mandate to assist in, and coordinate, the practical application of atomic energy for peaceful uses worldwide, has over 40 years of experience in providing radiation medicine expertise and technology to low and middle income countries. Thus, the WHO-IAEA Joint Programme provides the framework for the two organizations to combine their work, building on their areas of expertise to create a more coordinated and robust approach to combating cancer.

Building Better Agriculture

The link between atomic energy and agriculture has proven to be extremely valuable and unique in agricultural research and development. In 1964, the FAO’s atomic energy branch and the IAEA’s agriculture unit came together to become the Joint FAO-IAEA Division of Nuclear Techniques in Food and Agriculture. Since then, the Joint Division has made critical contributions to global efforts to combat hunger and attain food security. It operates with a staff of 100 scientists, technical experts and support personnel divided between offices and laboratories. It oversees an annual budget of approximately US $17.5 million, plus an additional US $10–14 million in technical cooperation projects, all geared to helping Member States solve practical agricultural problems with nuclear technology. Its research and development activities are broken into five separate but interrelated work areas: soil and water management and crop nutrition, plant breeding and genetics, animal production and health, insect pest control, and food and environmental protection.

The Joint Division fosters extensive cooperation and networking with national and international institutions and organizations. Its potential to secure extrabudgetary contributions is exemplified by current research and development projects funded by external partners, including the EU, UNFIP, UNTFS, USAID, USDA and the Wellcome Foundation.
Food and Agriculture

Building Better Agriculture
One Atom at a Time

Nuclear Technology: A Tool for Improving Agricultural Production

In a world facing the dilemmas posed by exponential population growth and changing climates, nuclear technology offers possible avenues to solve production problems, protect soil and water resources and conserve biodiversity, which, in turn, means increased hope for global food security. Application of nuclear technology has a proven record in increasing agricultural production. Higher and more reliable yields not only improve farmers’ livelihoods, they mean better quality and safer food for consumers.

The methods used vary: isotope measurements identify and trace the efficiency of crop inputs such as water and fertilizer and of animal feeds; gamma rays sterilize male insects so that when they are returned to the wild they are unable to produce progeny; irradiation stops the growth of pests and expands the shelf life of grains, spices and processed foods; radiation induced mutation speeds up natural genetic changes in crops to support plant breeders; and genetic markers expedite the identification of animal diseases thereby allowing treatment to begin sooner. All of these methods, plus a host of others that come under the heading of nuclear technology, are invaluable tools for agriculture and food production.

For almost five decades, the IAEA, together with its partner the FAO, guided development of new nuclear based methodologies, requested by its Member States and facilitated their adaptation, adoption and application. A harbinger of the United Nation’s Delivering as One, the Joint FAO/IAEA Division stands as the United Nations’ system’s only joint venture. It also operates its own agriculture and biotechnology laboratories in Seibersdorf where technical services, R&D and laboratory training activities are conducted in support of the development and transfer of new technologies and their adaptation to local needs and environments.

Developed through the use of nuclear techniques, Qatar is currently planning to use 60 million m$^3$ of treated sewage water to irrigate 83 300 ha of highly saline coastal and inland sabkha lands to produce livestock fodder, thereby increasing the country’s total arable land from 8000 to 91 000 ha.
The IAEA, together with its partner the FAO, works on developing and applying nuclear technologies in five areas:

**Soil and Water Management and Crop Nutrition:** Isotopic and radiation methods measure and monitor nutrients and water in the soil-crop system as the basis for strategies to ensure best results through the judicious and efficient use of scarce resources.

**Plant Breeding and Genetics:** Radiation creates variability in desired traits of food and industrial crops and is used to speed breeding of varieties that have higher yields and improved resistance to disease and to environmental stresses such as drought and salinity.

**Animal Production and Health:** Isotopes are used to develop diets and feeding strategies that improve productivity and reproductive efficiency while immunoassay methods help diagnose diseases and monitor effectiveness of disease control and eradication programmes.

**Insect Pest Control:** Sterile insect techniques offer alternative means of suppressing and, in some cases, even eradicating insects, such as fruit flies, tsetse flies, moths and malaria carrying mosquitoes.

**Food Safety and Control:** Irradiation provides a safe and environmentally friendly way of controlling food-borne diseases and stored product insect pests; other nuclear technologies are used to trace and authenticate food products and to detect, monitor and track the fate of contaminants in foods and the environment.

Different scenes, different parts of the world, but they are connected through nuclear technology. In each case, cutting edge nuclear technologies have added value to traditional farming and food systems by making it possible to:

- Speed up the genetic development of robust new crop varieties
- Control pathogen growth in grains and processed food
- Trace a crop’s uptake of water and sequestration of nitrogen
- Diagnose and treat animal diseases and maintain surveillance
- Control the presence of harmful pests in high cropping areas.

Global eradication of rinderpest will be officially declared in 2011: it was the most important livestock disease in Africa, costing the continent about US $5 billion per outbreak. The IAEA, the FAO, the OIE and the AU, have made a significant technical contribution over a period of almost 20 years, through the development, evaluation, validation and distribution of immunological and molecular nuclear and nuclear related technologies for the diagnosis and control of rinderpest.

California implements preventive releases of radiation sterilized medfly males to guard against the permanent establishment of this pest that could potentially cause economic losses of US $1.9 billion annually.

Mutation breeding has provided Vietnamese farmers from the Mekong delta and the highlands with higher yields and better market prices due to the high quality of mutant rice varieties. In highland areas, farmers are halting deforestation as they can now produce sufficient crops in lowland areas.

Analytical methods and protocols, developed under an IAEA coordinated research project and provided to Brazil, helped to address shortfalls in quality assurance and to ensure compliance with EU regulations on the safety of food commodities. This enabled Brazil to maintain trade in beef and poultry exports to the EU valued at €1.5 billion annually.
Environment Laboratories
Protecting the Environment

According to the Millennium Development Goals, managing the environment is considered an integral part of the global development process. The main purpose of the IAEA’s environment laboratories is to provide Member States with reliable information on environmental issues and facilitate decision making on protection of the environment. An increasingly important feature of this work is to assess the impact of climate change on environmental sustainability and natural resources.

The IAEA’s environment laboratories use nuclear techniques, radionuclides, isotopic tracers and stable isotopes to gain a better understanding of the various marine processes, including locating the sources of pollutants and their fate, their transport pathways and their ultimate accumulation in sediments. Radioisotopes are also used to study bioaccumulation in organisms and the food chain, as well as to track signals of climate change throughout history. Natural and artificial radionuclides are used to track ocean currents in key regions. They are also used to validate models designed to predict the future impact of climate change and ocean acidification.

The laboratories study the fate and impact of contamination on a variety of ecosystems in order to provide effective preventative diagnostic and remediation strategies. They enhance the capability of Member States to use nuclear techniques to understand and assess changes in their own terrestrial and atmospheric environments, and adopt suitable and sustainable remediation measures when needed.

Since 1995, the IAEA environment laboratories have coordinated the international network of Analytical Laboratories for the Measurement of Environmental Radioactivity, providing accurate analysis in the event of an accident or an intentional release of radioactivity.

In addition, the laboratories work alongside other organizations, such as UNESCO, the IOC, UNEP and the EC. The laboratories collaborate with Member States through direct involvement with their national bodies, scientific institutes, international and regional organizations, and through technical cooperation projects. They also disseminate knowledge by organizing international meetings, releasing publications, fostering e-learning and organizing training courses for students and scientists. By promoting excellence in environmental nuclear applications, the IAEA hopes to create a better understanding of the impact human activities have on the environment.
Providing Reference Materials

IAEA reference product services are provided by the environment laboratories to support Member States’ own laboratories in conducting quality of environmental sample analyses, interlaboratory comparison exercises and analytical quality control. Reference materials are available on-line via a webshop, allowing customers to know, in real time, what is in stock and how to obtain and track their order. In addition, proficiency tests allow Member States to receive performance assessments for their laboratories.

IAEA activities take place around the world and address terrestrial, atmospheric, freshwater and marine environments in a variety of ecosystems.

The environment laboratories assist in developing tools and in finding solutions for all types of environmental issue by providing reliable, comparable and ‘fit for purpose’ environmental assessments. In the case of global assessment, where decisions are made based on the information produced by different laboratories, these requirements are even more pronounced. The laboratories also help build capabilities at a regional level to reduce the anthropogenic and natural degradation of coastal ecosystems.

With an ongoing, three decade long relationship with the Mediterranean Long-Term Pollution Monitoring and Research Programme, the IAEA has a long record of close collaboration with numerous United Nations and regional organizations. In this particular project, the IAEA has been assisting national and regional laboratories to improve their analysis of trace metals and organic compounds in marine samples.

In one instance, the laboratories successfully developed a new analytical method to detect the presence of radionuclides in environmental samples, such as those that may occur during a nuclear accident. The method included a rapid and accurate determination of radioactive strontium in milk, one of the key pathways for human contamination. The test will be especially helpful in avoiding health risks to infants during cases of emergency.

Success Stories from the Field

A current project in the Arctic aims to assess the effect of climate change by conducting field observations that monitor the complex and rapidly changing Arctic environment and by providing data for modellers. Since 2009, the IAEA environment laboratories have been collaborating with Norway to conduct annual studies of the transportation of radionuclides into the Arctic sea.

Over the last three years, the laboratories have also assisted in establishing a nuclear analytical laboratory in Doha for the Qatar Ministry of Environment, where they installed the necessary equipment and trained the laboratory technicians.

Furthermore, the IAEA assists Member States around the world in protecting the quality of their seafood from increasing toxic algal blooms in coastal areas (southeast Asia, Latin America and southern Africa). In Argentina, for example, the laboratories were involved in an independent assessment of possible uranium contamination of soil, surface water and groundwater.
Meeting Millennium Development Goals

Access to safe water is a basic precondition of all the Millennium Development Goals (MDGs). Specifically, MDG 7 seeks to halve the proportion of the population without sustainable access to safe drinking water. Investigation and assessment of water sources is necessary to provide a comprehensive water resource assessment, thus leading to a sustainable system. The IAEA has projects focusing specifically on this issue, including the IAEA Water Availability Enhancement Project, which is currently developing templates and methodologies for national scale assessments of water resources.

Cooperation Is Key to Success

The IAEA supports technology transfer through the implementation of hydrology projects, training and technical analytical support, as well as by assisting in the procurement of equipment and expert services. The programme works to manage and enhance regional projects, including promotion of exchanges between neighbours. The IAEA supports the development of a community of experts who can oversee local projects. The IAEA grants research contracts to universities, research centres and other Member State institutions to support innovative research in the field of isotope hydrology. The programme works in cooperation with other United Nations (UNDP, UNEP, UNESCO), national (USGS, GTZ, etc.) and international (WB, GEF, OAS) bodies. The Isotope Hydrology Laboratory plays an important role in providing access to laboratory services for analysis and quality assurance and in support of global databases.

Isotope Hydrology
Ensuring Water Now and for the Future

Water Is Essential for Development

Providing adequate freshwater of a desired quality to their populations is one of the foremost development challenges faced by Member States. Although water is a basic human need, it is estimated that nearly one billion people in developing countries do not have access to safe drinking water and more than two billion lack basic sanitation facilities due to inadequate water availability. According to the World Health Organization, nearly five million people – mostly children – die each year from preventable, water-borne diseases. Increasing population, irrigated agriculture and industrial growth together have stressed global freshwater resources over the past several decades. In addition, climate change and the need for greater energy production are now significant drivers of stress on water resources.

Nearly 40% of world food production is achieved by means of irrigated agriculture, which accounts for about 70% of total freshwater withdrawals. A significant proportion of groundwater used for irrigation comes from fossil or non-renewable sources, making the food supply unsustainable for a growing human population. Nearly one in three people depends upon water from rivers that are fed by glaciers and snow melt. Increased variability and vulnerability of river flows in a warmer climate (due to increased glacial melt and changes in precipitation patterns) will drive the need for changes in water use and management practices. These changes may also include greater dependence on already stressed groundwater resources. Nearly four billion people – half of the world’s population – may live under conditions of water stress in the next two decades.

Supporting Member States

The IAEA works together on technical cooperation projects to address priority water issues in Member States. Training, meetings, technical expertise and infrastructure support aid in capacity building so that Member States can address their practical problems. Currently, nearly 70 water resource projects exist in Africa, Asia, Europe and Latin America, which address a variety of groundwater and surface water resource issues. These include characterizing and monitoring transboundary aquifers, such as the Nubian Sandstone Aquifer System and the Guarani Aquifer System, as well as river basins, such as the Nile basin. Coordinated research projects support international research efforts to develop new scientific approaches to relevant themes.
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The IAEA has been using isotope techniques – together with other donor agencies – to help mitigate the impacts of arsenic poisoning in Bangladesh, where groundwater is the main source of drinking water. Elevated arsenic concentrations in groundwater had created a major public health crisis. A short study conducted by the IAEA indicated pollution sources linked to young groundwaters, uncovered the nature of the problem and provided information about where to find safe sources.

Groundwater in the Nubian Sandstone Aquifer System has been identified as the largest and in some cases the sole future source of water capable of meeting the growing demands of the four countries overlying the aquifer – Chad, Egypt, the Libyan Arab Jamahiriya and Sudan. Isotopes and models allowed the assessment of intensive pumping, showing how it can lead to local hydraulic effects. Isotopes were used to uncover the nature of the aquifer and determine how pumping effects are linked beyond national boundaries.

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Isotope Hydrology

Ensuring Water Now and for the Future

The Science

During evaporation and condensation within the water cycle, the concentrations of oxygen and hydrogen isotopes – naturally occurring atoms of different mass – change, allowing distinct identification of water from different environments. There are other isotopes in rainwater, such as tritium (3H) and carbon-14 (14C), the concentrations of which decrease with time and allow the estimation of water age. The IAEA has played a key role in the development and promotion of isotope hydrology tools in the context of water resource assessment and management.

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Human Health
Improving Health Around the World

Building Capacity in Nuclear Medicine and Diagnostic Imaging

Every year, millions of nuclear medical examinations are conducted around the world using radiopharmaceuticals that assess diseases at molecular levels. Diagnostic images are then generated to help diagnose and treat major disorders and illnesses such as heart disease and cancer.

Positron emission tomography in oncology and single photon emission tomography in cardiology (as well as in other areas) provide unique functional information that, when combined with anatomical data obtained by magnetic resonance imaging or computed tomography, allow for more precise localization of cancer or cardiac abnormalities. By facilitating appropriate human resources capacity building, the IAEA helps to establish new, and improve existing, nuclear medicine facilities, and encourages nuclear medicine imaging integration with diagnostic radiology procedures, thus helping its Member States to achieve and maintain high standards of professional practice.

Promoting Radiation Oncology for Cancer Treatment

By 2020, up to 15 million people worldwide will be diagnosed with cancer every year, with 70% of these new cases occurring in the developing world. Radiotherapy is an essential component in the treatment of cancer for both cure and palliation. It has also been proven to be a cost effective modality. To address the shortage of cancer treatment resources in low to middle income countries, the IAEA provides expertise in radiation oncology and works with a variety of stakeholders, including other organizations within the United Nations, hospitals, governments and research institutes. In addition, in order to achieve the optimal use of radiotherapy, this modality must be part of a comprehensive cancer control programme that also includes effective prevention and early detection measures. In this context, the IAEA works to promote effective and safe radiotherapy services in Member States.

The IAEA also promotes and coordinates research in clinical radiation oncology and applied radiation biology. Technical expertise in these fields is provided through technical cooperation projects, which directly address cancer management in many countries around the world.
The objective of the IAEA in the area of radiation oncology is to enhance Member States’ capabilities to establish sound policies for radiotherapy and cancer treatment, and to ensure the effective, efficient and safe utilization of current and future advances in radiotherapy. Member States receive assistance in modernizing and establishing new radiotherapy facilities, brachytherapy services, new technologies and education programmes.

Ensuring High Quality Dosimetry and Medical Radiation Physics

Medical procedures utilizing radiation play a central role in modern health care. To ensure maximum benefits and minimal risks, it is essential that these techniques rely on adequate dosimetry (i.e. dose measurement) and medical physics procedures.

In therapeutic procedures, accurate dose measurement and delivery are critical for effectively treating patients. In diagnostic imaging, quality assurance processes enable accurate image generation with minimal radiation dose to patients and medical personnel. The IAEA contributes to ensuring the safe and effective use of radiation in medicine through its activities in dosimetry and medical radiation physics. Through the IAEA–WHO network of secondary standards dosimetry laboratories traceable dosimetry calibrations services are provided. Independent dosimetry audits for radiotherapy centres are conducted in conjunction with WHO and comprehensive clinical audits are offered by the IAEA to radiation medicine facilities around the world.

One ongoing project aims at developing, in collaboration with professional societies, guidelines on the dosimetry of small and composite fields used in novel radiotherapy techniques. These guidelines are needed to ensure standardization and harmonization of dosimetry practices and will contribute to the safe and effective implementation of new radiotherapy treatment modalities worldwide.

Fighting Malnutrition with Nuclear Techniques

One out of every ten children born in developing countries will die before their fifth birthday as the result of malnutrition. In total, about ten million children die each year. This extremely high death toll demonstrates the vulnerability of infants and young children to poor nutrition and health. Fighting malnutrition is a key part of the IAEA’s agenda in its efforts to contribute to Millennium Development Goal #4 to reduce the mortality rate among children under five years of age by two thirds.

The IAEA assists Member States in their efforts to develop effective, evidence based interventions to combat malnutrition using stable (non-radioactive) isotope techniques. For example, as recommended by the WHO and UNICEF, exclusive breastfeeding during the first six months of life is vitally important for a child to begin a healthy life.

Tackling Infant Malnutrition with Stable Isotope Techniques

By using a stable isotope technique in which the mother is given a dose of deuterium oxide, data can be generated on the total volume of human milk consumed by the baby over a period of fourteen days, as well as information gathered on whether the baby was exclusively breastfed or not.

For the first time ever, this methodology is being used in fifteen African countries to collect a large data set on human milk intake and the prevalence of exclusive breastfeeding.
Comprehensive Cancer Control
Fighting Cancer in the Developing World

For over thirty years, the IAEA has worked in some 115 low and middle income (LMI) Member States to deploy robust radiotherapy and nuclear medicine programmes, expending over US $250 million on cancer related assistance under its Technical Cooperation Programme, with technical support provided by the Division of Human Health. This has enabled many Member States to establish safe and effective diagnostic imaging and radiation therapy capacity to provide treatment and higher quality care to many of their cancer patients. The IAEA also helps establish new nuclear medicine facilities and encourages their integration with diagnostic radiology procedures by facilitating appropriate human resources capacity building. This helps Member States to achieve and maintain high standards of professional practice. The IAEA addresses quality management though services such as the Quality Assurance in Nuclear Medicine (QUANUM), Quality Assurance Team in Radiation Oncology (QUATRO) and Quality Assurance in Diagnostic Radiology (QUADRIL), which allow the IAEA to provide tools for improving the practice of radiation medicine around the world.

In 2004, the IAEA established the Programme of Action for Cancer Therapy (PACT) in support of the World Health Assembly’s call to action against cancer. It stands as the IAEA’s umbrella programme for combating cancer and builds upon the above experience in radiation medicine expertise and technology. PACT works closely with the World Health Organization (WHO), its regional offices and other key players through the WHO-IAEA Joint Programme on Cancer Control. The WHO-IAEA Joint Programme was established in 2009 to enable LMI Member States to introduce, expand and improve their cancer treatment capacities and therapeutic effectiveness by integrating radiotherapy into a comprehensive national cancer control programme.

Cancer: An Emerging Epidemic

Cancer is an enormous — and growing — global public health problem. In 2010, cancer killed nearly eight million people worldwide, while over 13 million new patients were diagnosed with the disease. Formerly considered more pervasive in affluent countries, cancer now places its heaviest burden on poor and disadvantaged populations.

According to the WHO, more than two thirds of new cases and cancer deaths occur in LMI countries, where such numbers are increasing at alarming rates. In some low income countries, fewer than 15% of breast and cervical cancer patients survive longer than five years following diagnosis, despite both being highly curable diseases elsewhere in the world.

Cancer deaths in LMI countries are expected to increase at double the rate of high income countries over the next 20 years.
PACT activities are focused in the following areas:

- The **imPACT Review** is a service offered to Member States by the IAEA with support from PACT partners to assess a country’s readiness to develop and implement a long term radiation medicine capacity building plan within the framework of a national cancer control programme. Additionally, these reviews determine a country’s cancer related needs and advise on immediate actions. An imPACT Review may be followed by a WHO-IAEA Joint Cancer Control Assessment Mission, which is a complete review of a country’s cancer burden and cancer control strategies and plans. During such a mission, a team of international experts evaluates the burden of cancer in the State, assesses its existing capacity for cancer control and uncovers any deficiencies in cancer care, in order to support national authorities in developing targeted responses to the cancer crisis. The recommendations of the mission help a Member State to develop the appropriate strategies, action plans, programmes, policies, capacities and infrastructure necessary for the expansion of national cancer capacity.

- PACT **Model Demonstration Sites (PMDS)** are the focus of comprehensive, integrated and multidisciplinary efforts to address all facets of cancer control. These sites are designed to showcase the synergies that international partners can achieve by working together with national counterparts to advance comprehensive cancer capacity building in LMI nations. The strategic objective of each model is to create infrastructure and comprehensive capacity within their national health care systems.

- The **Advisory Group on increasing access to Radiation Therapy (AGaRT)** is a multi-stakeholder consortium to address the needs in, and shortage of, radiotherapy services in developing countries. It promotes increased access to radiation based diagnostic and therapeutic technologies in developing countries by encouraging the industry to offer complete and integrated solutions that are safe, affordable, highly reliable and effective for low resource settings.

- The **Virtual University for Cancer Control (VUCCnet)** is a pilot project that aims to contribute to ongoing efforts by Member States to address the shortage of cancer control professionals by using modern pedagogical IT assisted methodologies and e-learning in conjunction with traditional teaching approaches. The pilot phase of the project is financed by the Roche African Research Foundation and the US Government. To ensure the effectiveness and sustainability of the pilot project outcomes, the IAEA is working in collaboration with its international partners in cancer control as well as the Member States.

The IAEA also aims at facilitating donor interest and working at the United Nations level in order to place cancer treatment and care on the global development agenda.

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**Radiation Medicine in Brief**

Radiation medicine includes radiotherapy, diagnostic radiology, nuclear medicine and medical physics.

**Radiotherapy or radiation oncology** involves treating cancer by radiation through external beam or brachytherapy (internal radiation where the radioactive source is placed directly into the tumour or close to it).

**Nuclear medicine** uses techniques that employ unsealed radioactive material in the diagnosis or treatment of cancer.

**Medical physics** ensures the safe and effective diagnosis and treatment through comprehensive quality assurance.

**Dosimetry**, which refers to the accurate measurement of radiation doses, is essential to enable patients to receive proper medical treatment. By providing dosimetry calibration and audit services to Member States, the IAEA has improved the quality and consistency of radiation dosimetry in national laboratories and medical institutions worldwide.

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82 countries have requested assistance to date.

- **PACT Model Demonstration Site (PMDS)** [8]
- **Already received a preliminary or full imPACT review** [27]
- **Planned to receive an imPACT review** [47]
- **Major donor countries** to PACT

Donor countries to PACT includes countries that have contributed $10 000 or more to PACT Programme, excluding the cash contributions given by the 58 Member States from the 2004 cash surplus, and other donors, such as OPEC Fund for International Development, F. Hoffmann-La Roche Ltd, UN Women’s Guild and UN Federal Credit Union.
Radioisotope Production and Radiation Technology

Contributing to Better Health Care and a Cleaner Environment

Radioisotope and radiation technology finds numerous applications in a wide variety of fields, most importantly in medicine, industry, agriculture and the environment. However, in order to take full advantage of the benefits offered by this technology, it is essential to provide the necessary infrastructure as well as qualified personnel. The IAEA strives to promote worldwide availability of products and facilities in order to offer the benefits of radioisotope products and radiation technology to developing countries. In particular, the IAEA helps Member States to achieve self-sufficiency in the production of radioisotopes and radiopharmaceuticals, strengthen quality assurance practices and regulatory compliance as well as facilitate human resources development. The multipronged need based approach includes providing advice, assistance and capacity building support for:

- Development, production and quality assurance of reactor and accelerator based medical isotopes and radiopharmaceuticals for both the diagnosis and treatment of diseases, especially cancer;
- Establishment of irradiation facilities and utilization of gamma radiation, electron beam treatment, sterilization of medical products, wastewater treatment, stabilization of medical products, disinfection of food grains, and synthesis and characterization of advanced materials;
- Application of radiation and isotopes in industrial process management.

Facilitating the Supply of Molybdenum-99 (\(^{99m}\)Mo) and Technetium-99m (\(^{99m}\)Tc)

The shortages in the supply of fission produced \(^{99m}\)Mo and \(^{99m}\)Tc producing generators during 2007–2010 attracted international attention and directly affected patient care, since more than 30 million diagnostic investigations are carried out annually worldwide using \(^{99m}\)Tc. In this context, the IAEA has been working towards ensuring the sustained supply of \(^{99m}\)Mo to all Member States. While on the one hand coordination efforts with the OECD Nuclear Energy Agency to address the production and supply of \(^{99m}\)Mo on a large scale are expected to have a desirable outcome, the IAEA is also exploring alternative technologies for \(^{99m}\)Mo production. One promising example is the cyclotron based direct production of \(^{99m}\)Tc proposed by Canadian researchers, which is being examined as a practical solution to at least partly alleviate shortages in countries that have cyclotrons available for use.

Enabling Wastewater Reuse Through Radiation Processing Technology

Chronic shortages of water in arid and semi-arid regions of the world and environmental policy regulations have stimulated the use of innovative technologies in treating wastewater for reuse for urban irrigation, gardens and parks, industry, cleaning purposes, etc. Standard biological processes commonly used for wastewater treatment are not capable of neutralizing many of the complex organic chemicals found in varying quantities in wastewaters.

Electron beam or gamma irradiation can treat such pollutants, transforming them into less harmful substances or reducing them to levels below permissible concentrations. On the industrial scale, the combined biological and electron beam treatment of wastewater from textile dyeing is in operation in the Republic of Korea, where more than 10,000 m\(^3\) of wastewater is successfully treated per day. Based on this successful example of radiation treatment for water remediation, the IAEA has launched a coordinated research project to assist Member States in developing strategies to address the issue of wastewater treatment in their countries using electron beam or gamma radiation.

Quick Facts

- Diagnostic radiopharmaceuticals used in conjunction with modern medical imaging devices such as gamma camera and PET-CT scanners are used to diagnose specific pathological conditions such as cancer, cardiac disorders and neurological conditions much earlier than was previously possible.
- Therapeutic radiopharmaceuticals, most often used in the treatment of cancers, are designed as ‘smart’ molecules to target cancerous cells and subject them to a payload of lethal dose radioactivity. On successful targeting, radiation damages the structure of the cancerous cells, thus creating a therapeutic effect and ultimately leading to complete destruction of the cancerous tissue.

Optimizing Industrial Processes

The oil and gas industry is vital in many Member States, and inspection of oil and gas pipelines to assess corrosion is necessary to ensure safety. Computed tomography (CT) using gamma rays is a rapid, sensitive and effective imaging technique increasingly used by industry to uncover corrosion and defects in the metal structure of pipelines. The IAEA has supported the development of simple transportable gamma CT systems in several Member States, such as Vietnam, primarily for oil and gas pipeline scanning.

Preserving and Protecting Our Past

For the past 40 years, radiation treatment has been successfully used in the preservation of a large variety of cultural heritage artifacts, such as furniture, statues, archaeological objects, ethnographic collections, mummmies, books, leather, porous stones, tiles, mosaics, frescos and textiles. The IAEA assists Member States in developing and establishing radiation processing technology for preservation of their cultural heritage artifacts by setting up facilities as well as training personnel. Several Member States worldwide are using this technology in cooperation with conservators, curators and restorers to preserve the world’s cultural heritage.

Quick Facts

- Ionizing radiation can be a powerful tool for the deactivation of microbes, either to address threats to public health and safety that might be posed by deliberate or inadvertent biohazard contamination, or to treat wastewaters for reuse in the industrial, agricultural and horticultural sectors, as well as for the preservation of cultural heritage artefacts.
- Radiation treatment of volatile organic compounds and hazardous chemical agents can be highly effective in neutralizing harmful pollutants.
- Radiotracers and non-destructive testing (NDT) aid immensely in improving productivity in terms of yield, quality and optimal energy utilization. Radiotracers have been extensively used in a wide variety of applications in the chemical industry, such as process optimization, troubleshooting, measurement of residence times at different stages in chemical processing, etc.
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Developing Member States have also taken on a fresh interest in the role of research reactors (RRs) in nuclear science development and applications. The IAEA’s RR thrust is fourfold: (i) assistance to support sustainable and strategic utilization of reactors and encouragement of networking and coalitions among RRs which serve nuclear applications in developing countries; (ii) support to strengthen the management of RR operations with a view to enhancing their availability for certain vital applications such as isotope production; (iii) assistance and guidance on infrastructure, including existing RRs and regional RRs; and (iv) facilitation of the conversion of reactors to the use of low-enriched uranium fuel and targets, and return of fresh and spent highly enriched uranium (HEU) fuel to the countries where it originated. The IAEA continues to place emphasis on activities that minimize the use of HEU in RRs and other experimental facilities.

The IAEA’s support of nuclear fusion research focuses on fostering international cooperation in the two major approaches of magnetic confinement and inertial fusion. The International Thermonuclear Experimental Reactor (ITER) aims to demonstrate the scientific and technological feasibility of fusion energy. The IAEA has been actively involved in the ITER project from its inception, providing practical support such as the publication of technical documents and the ITER newsletter.

Meeting the Growing Demand for Nuclear Techniques

The effective development of new nuclear technologies and their applications, as well as the safe and cost effective maintenance of existing technologies, is essential for countries considering adopting radiation and nuclear techniques for non-energy applications. The interest in nuclear power around the world and the widespread adoption of radiation and nuclear techniques for non-energy applications are major drivers behind the IAEA’s continued involvement in strengthening nuclear science capabilities in interested Member States.

Accelerator facilities represent one means of growth for nuclear science, education and training. The application of accelerators for supporting materials research, analytical sciences, advisory missions, laboratory training and analytical services, publication of state of the art reports on specific topics and issues, and preparation and provision of materials for human resources development. Such activities address the requirements of both nuclear energy systems and non-power nuclear applications.

Meeting the Growing Demand for Nuclear Techniques

The IAEA’s nuclear science programme supports Member States in maintaining and developing innovative nuclear education, training in nuclear sciences and using sustainable technologies.

The IAEA’s activities in fusion focus on increasing international cooperation and support for the development of fusion power plant science and technology. This approach includes the use of smaller facilities in about 40 Member States for proof-of-principle experiments and basic research and training for scientists. Additional attention will be given to encourage talented female and male scientists to pursue higher education and research in nuclear fusion.

A major research activity is X-ray fluorescence spectroscopy, which is used worldwide for the analysis of geological materials, the monitoring of environmental pollution and the study of cultural heritage objects.
Developing Member States have also taken on a fresh interest in the role of research reactors (RRs) in nuclear science development and applications. The IAEA’s RR thrust is fourfold: (i) assistance to support sustainable and strategic utilization of reactors and encouragement of networking and coalitions among RRs which serve nuclear applications in developing countries; (ii) support to strengthen the management of RR operations with a view to enhancing their availability for certain vital applications such as isotope production; (iii) assistance and guidance on infrastructure, including existing RRs and regional RRs; and (iv) facilitation of the conversion of reactors to the use of low enriched uranium fuel and targets, and return of fresh and spent highly enriched uranium (HEU) fuel to the countries where it originated. The IAEA continues to place emphasis on activities that minimize the use of HEU in RRs and other experimental facilities.

The IAEA’s support of nuclear fusion research focuses on fostering international cooperation in the two major approaches of magnetic confinement and inertial fusion. The International Thermonuclear Experimental Reactor (ITER) aims to demonstrate the scientific and technological feasibility of fusion energy. The IAEA has been actively involved in the ITER project from its inception, providing practical support such as the publication of technical documents and the ITER newsletter.

The Future of Applied Nuclear Sciences

The IAEA supports Member States’ needs based development efforts through technical cooperation programmes, coordinated research activities, advisory missions, laboratory training and analytical services, publication of state of the art reports on specific topics and issues, and preparation and provision of materials for human resources development. Such activities address the requirements of both nuclear energy systems and non-power nuclear applications.

In light of the current growing interests and commitment towards opting for nuclear power, qualified human resources are vital. In the future, human resources will be needed not only to ascertain the safe and continuing operation of exiting nuclear programmes, but also to develop and implement new and expanding ones. The IAEA nuclear science programme supports Member States in maintaining and developing innovative nuclear education, training in nuclear sciences and using sustainable technologies.

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Accelerator facilities represent one means of growth for nuclear science, education and training. The application of accelerators for supporting materials research, analytical sciences for environmental purposes and the development of nuclear energy systems remains a field of high interest for both developed and developing countries. Materials science studies using accelerators, neutron beam techniques and nuclear analytical methods are important for advanced reactors and nuclear fuel cycles, as well as for fusion research, and all these areas are addressed by the IAEA’s programmes.

Nuclear Physics

Facilitating the Peaceful and Practical Uses of Nuclear Science

When properly applied, nuclear science—the study of atomic nuclei and other subatomic particles — can contribute in many ways to the health, development and security of communities around the world. In this context, the IAEA plays an important role in helping interested Member States develop the capabilities and infrastructure necessary to manage their own programmes devoted to nuclear and radiological applications.

The IAEA’s nuclear science programme helps Member States to establish sound frameworks for the efficient, safe and secure use of new nuclear technologies, including accelerator facilities, research reactors and future nuclear fusion facilities. By applying nuclear technologies in a wide variety of areas such as energy production, health care, food and agriculture, industry and the environment, Member States can benefit immensely from the ensuing socioeconomic developments, as well as providing better living conditions for their citizens.

Meeting the Growing Demand for Nuclear Techniques

The IAEA’s nuclear science programme supports Member States in optimizing the utilization of accelerator based technologies, which can be adopted for a variety of purposes, including the analysis of archaeological findings or for use by museum curators. For example, the techniques afforded by accelerator based technologies allow scientists to recognize the elemental composition of pigments or materials of art pieces in order to detect forgery, determine provenance and better understand the methods of production.

“Building and maintaining scientific and technological capacities is key to achieving the Millennium Development Goals in Member States.”

Daud Mohamad
Deputy Director General
Department of Nuclear Sciences and Applications

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The IAEA supports nuclear research activities in Member States by providing essential nuclear data and serving as the central agency for the collection and dissemination of data from laboratories worldwide. The EXFOR database contains a compilation of experimental reaction data from all around the world, and this effort — led by the IAEA — has been very well received, as it provides invaluable data for nuclear calculations and evaluations to researchers in Member States. ENSDF is a collection of evaluated data on the structure and decay properties of radioactive nuclides collected worldwide through a network coordinated by the IAEA.

The IAEA has also developed tools to allow users to visualize data, since visual presentation of data in the form of a plot makes them easier to understand and appreciate. Two important applications are available from the Nuclear Data Services web site: LiveChart interactively presents nuclide properties, and ZView plots reaction cross-sections, both from evaluated files and from EXFOR, as 2-D or 3-D plots.

Concerted efforts by the IAEA include coordination of activities in Member States, such as EXFOR and ENSDF, coordinated research project (CRP) implementation, and also staff efforts, which have resulted in data libraries of immense value.

IBANDL and RPL-3 are examples of two databases resulting from CRPs. IBANDL is a database of experimental and evaluated nuclear cross-sections relevant to ion beam analysis. RPL-3 is a library of reference input parameters which are essential ingredients of theoretical modelling codes. By providing a complete set of verified parameters, it is ensured that evaluations carried out around the world are compatible and can be produced easily and efficiently.

Quick Facts

- The Medical Portal provides a unified view of medical applications, including databases, documents, libraries and ongoing projects. Links to diagnostic and therapeutic radioisotope production, heavy charged particle interactions and phase-space databases are only a mouse click away.
- Nuclear Data for Safeguards provides a handbook of relevant data, both as a downloadable report and in the form of individual data tables. In addition, a specially customized LiveChart application provides safeguards data interactively.
- Evaluated nuclear data libraries in ENDF format have been produced by many data centres throughout the world. Twenty-six of these libraries can be interrogated and cross-section data plotted. Experimental data from EXFOR can then be added to provide evaluation validation.
- Covariance data enable uncertainties in quantities to be calculated. When a physical quantity depends on several variables, then correlations between these variables are needed to provide an accurate estimate of uncertainty. The figure above right shows a typical 3-D plot.
- The EXFOR database covers about 19000 experiments and contains about 11.5 million data points. Data have been compiled since 1935 and cover reactions induced by neutrons, charged particles and photons.
- Nuclear data are available by directly downloading or by requesting documents or other media such as DVDs and CDs.

Nuclear Data: Fundamental for applications

Nuclear and atomic data are essential for many applications such as:

- Nuclear power (fission)
- Research reactors
- Nuclear fusion
- Medicine
- Non-destructive testing
- Environmental monitoring

Database Glossary:

- ALADDIN – Database of numerical and molecular data
- AMBDAS – Database of bibliographic references to atomic and molecular papers
- ENDF – Format of evaluated nuclear data libraries, also the name of a set of evaluated data files
- ENSDF – Database of nuclear structure and decay properties
- EXFOR – Database of measured nuclear reaction data
- IBANDL – Database of nuclear reaction data for ion beam analyses
- RPL – Database of parameters used in theoretical calculations
- GENIE – Search engine for numerical data about atoms in plasma

The scope of atomic and molecular data is so large that an exciting new way of describing it has been implemented through the Knowledge Base for Atomic, Molecular and Plasma Material Interaction Data for Fusion, which is a "wild" based page that users can directly add to.
Securing A Better Future For All

Nuclear Techniques for Global Development and Environmental Protection

Nuclear and Atomic Data

Providing Values for Science

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Atomic Data: Supporting Fusion Technology

Fusion programmes all over the world rely heavily on atomic and molecular data, and although at present these data support research, with the construction of ITER the focus will switch towards the use of this technology for energy production. The same approach is followed for these data as for nuclear data, namely, the development of high quality data through CRPs and dissemination through web pages.

ALADDIN is the main database for numerical data covering collisions of electrons and heavy particles with atoms, ions and molecules, as well as for particle-surface interactions. The search engine GENIE provides a common query interface to many distinct databases for atomic processes. Bibliographic information for atomic processes can be found in the AMBDAS database.

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Neutron induced fission reaction.