

JOURNEYS TO SUCCESS

A collection of success stories from IAEA technical cooperation
in Asia and the Pacific



IAEA

International Atomic Energy Agency

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PREFACE

The technical cooperation programme is the International Atomic Energy Agency's primary mechanism for transferring nuclear technology to Member States, helping them to address key development priorities in areas such as health and nutrition, food and agriculture, water and the environment, industrial applications, and nuclear knowledge development and management. The programme also helps Member States to identify and meet future energy needs, and assists in improving radiation safety and nuclear security worldwide, including through the provision of legislative assistance.

Together with project counterparts, National Liaison Officers (NLOs) and National Liaison Assistants (NLAs) play an essential role as focal persons, supporting IAEA activities in their respective countries. It is very important to sustain consultative channels with senior NLOs and NLAs on ways to enhance the efficiency of the TC programmes, and to orient new NLOs and NLAs on existing mechanisms for delivering the TC Programme.

The IAEA Department of Technical Cooperation organizes a workshop for NLOs and NLAs every year for this purpose. In 2019, the workshop focused on 'Enhancing the Efficiency and Effectiveness of the Technical Cooperation Programme in Asia and the Pacific'. During the workshop, the participants decided to produce a document showcasing IAEA technical cooperation projects that have successfully brought positive change to the socioeconomic lives of the people in the Asia and the Pacific region.

This publication is the result of that decision – the success stories presented in these pages highlight the challenges, actions taken to meet them, and the positive socioeconomic impact of the project achievements. Each story, or 'journey to success' describes difficulties faced along the way and how they were overcome. The stories also highlight milestones that could prove helpful to other project counterparts and decision makers in the region, who may be facing similar challenges or launching similar projects.



IAEA Director General Rafael Grossi

MESSAGE

from the IAEA Director General

The IAEA technical cooperation programme has a special place in my heart. My first meetings at the Agency, as a young diplomat in 1986, were about TC programmes in my country.

Our technical cooperation programme has made a huge contribution over the decades. And nowhere is that more visible than in the many journeys to success presented in this book.

The Agency helps countries to build up technical expertise and establish appropriate regulatory systems so they can use nuclear technology to improve the quality of life of their people and achieve the Sustainable Development Goals.

We address some of the key problems facing the world today, including climate change, energy and food shortages, and pollution of the oceans and seas.

I hope you will find the stories in this book both inspiring and insightful and that they will give you a deeper understanding of the remarkable benefits of applications of nuclear technology for peace and development.



Deputy Director General Dazhu Yang

MESSAGE

from the IAEA Deputy Director General for Technical Cooperation

In 2019, the TC Programme assisted 38 countries and territories in the Asia and the Pacific region in areas including health and nutrition, food and agriculture, energy, nuclear knowledge development and management, water and the environment, safety and industrial applications and radiation technology, through 258 national and 65 regional projects.

The success of the TC programme rests on the joint efforts of countries and the IAEA Secretariat. This publication, written by National Liaison Officers and National Liaison Assistants from over 30 countries and territories in the Asia and the Pacific region, offers readers an excellent overview of concrete achievements and impact made through the programme, including their contribution to the achievement of the Sustainable Development Goals..

Stories range from building capacities in non-destructive testing in Malaysia to creating plant growth promoters from seaweed in the Philippines; from establishing a roadmap for nuclear power in Sri Lanka to helping Pacific Island states work together to address common challenges.

It is with a sense of great pride that I share in the challenges, actions and accomplishments of the region during its many journeys to success. I also look forward to our continued cooperation in bringing the benefits of nuclear technology for peace and prosperity in Asia and the Pacific.



Dr Jane Gerardo-Abaya

MESSAGE

from the Director, IAEA Division for Asia and the Pacific

The Asia Pacific region has a very active technical cooperation programme, with a broad scope of thematic areas and countries. Across the region, the IAEA's TC Programme effectively contributes to socioeconomic development by supporting Member States to attain self-reliance and sustainability of their national programmes in the peaceful applications of nuclear technology.

The examples and lessons learned that have been catalogued in this compendium will serve to guide, inspire and maximize the participation of Member States in the programme. This compendium of success stories provides us with a great opportunity to further increase the impact of our activities in the region by learning from each other's journeys to success, demonstrating that substantive progress can be achieved from modest beginnings.

Together with the staff of the IAEA Division for Asia and the Pacific, I would therefore like to congratulate our Member States in the region for their notable achievements, and look forward to reading many more success stories in technical cooperation in the years to come.

TABLE OF

	AFGHANISTAN : STRENGTHENING REGULATORY OVERSIGHT AND RADIATION PROTECTION	8
	BANGLADESH : NUCLEAR TECHNOLOGIES FOR FOOD SECURITY	10
	BAHRAIN : DETERMINING PESTICIDE RESIDUES IN FOOD AND WATER	12
	BRUNEI DARUSSALAM : DEVELOPING RADIOTHERAPY TREATMENT CAPABILITIES	14
	CAMBODIA : ESTABLISHMENT OF FIRST NATIONAL CANCER CENTRE	16
	CHINA : MUTANT GENE DISCOVERY FOR BETTER CROPS	18
	INDONESIA : ACHIEVING SELF SUFFICIENCY IN SOYBEAN PRODUCTION	20
	ISLAMIC REPUBLIC OF IRAN : THIRTY-YEAR JOURNEY TO RADIOPHARMACEUTICALS SUPPLIER STATUS	22
	IRAQ : LOOKING AHEAD TO THE FUTURE	26
	ISRAEL : STRENGTHENING EDUCATION/TRAINING IN RADIATION PROTECTION	28
	JORDAN : THE LIGHT OF SESAME: A DREAM COMES TRUE	30
	KUWAIT : COMPETENCE IN SUSTAINABLE GROUNDWATER MANAGEMENT	32
	LAO PEOPLE'S DEMOCRATIC REPUBLIC : RAPID DIAGNOSIS OF TRANSBOUNDARY ANIMAL DISEASES	34
	LEBANON : NUCLEAR ANALYTICAL TECHNIQUES IN FRAUD DETECTION	36
	MALAYSIA : SUPPORTING INDUSTRIAL COMPETITIVENESS WITH NON-DESTRUCTIVE TESTING	38
	MARSHALL ISLANDS : FOR THE GOOD OF MANKIND	42
	MONGOLIA : SUCCESS IN THE HEALTH SECTOR	44

CONTENTS

	MYANMAR : BUILDING CAPACITY IN VARIOUS NUCLEAR TECHNIQUES	46
	NEPAL : STRENGTHENING NUCLEAR EDUCATION AND TRAINING	48
	OMAN : ON THE ROAD TO MALARIA-FREE STATUS	50
	PACIFIC ISLAND STATES : TAKING A SUB-REGIONAL APPROACH TO SHARED CHALLENGES	54
		
	PAKISTAN : MUTANT COTTON: A SUCCESS STORY	56
	THE TERRITORIES UNDER THE JURISDICTION OF THE PALESTINE AUTHORITY : ESTABLISHING A LEGAL AND REGULATORY INFRASTRUCTURE	58
	PHILIPPINES : TURNING SEAWEED INTO A PLANT GROWTH PROMOTER	60
	QATAR : DETECTING RADIOACTIVE CONTAMINANTS IN FOOD IMPORTS	62
	SAUDI ARABIA : PROGRESS IN THE NUCLEAR ENERGY PROGRAMME	64
	SINGAPORE : DEVELOPMENTS IN RADIATION MONITORING AND NUCLEAR MEDICINE	66
	SRI LANKA : ESTABLISHING A ROADMAP FOR A NUCLEAR POWER PROGRAMME	68
	SYRIAN ARAB REPUBLIC : MONITORING VETERINARY DRUG RESIDUES IN FOOD	70
	THAILAND : RADIATION PROCESSING: FROM LABORATORY TO MARKET	72
	UNITED ARAB EMIRATES : SUPPORTING A MODEL NUCLEAR NEWCOMER	74
	VIET NAM : TRIANGULAR COOPERATION FOR DEVELOPMENT	80
	YEMEN : ENSURING FOOD SECURITY WITH NUCLEAR TECHNIQUES	82

AFGHANISTAN

STRENGTHENING REGULATORY OVERSIGHT AND RADIATION PROTECTION

THE SITUATION

After a decade-long hiatus owing to the geopolitical situation in the country, Afghanistan has begun to use nuclear science and technology in key sectors of the economy including health care, security and the industrial sector, such as oil and gas. Other applications include the use of nuclear gauges in construction and other industrial applications to perform precise measurements. The role of nuclear technologies is expected to further increase with the growth of these sectors in the coming years.

Afghanistan is, therefore, working towards establishing the country's nuclear safety infrastructure with emphasis on the National Regulatory Authority as the centre piece for the control of all radiation and nuclear activities. As such, Afghanistan requires international assistance, as well as technical and management advice, to better improve the quality of the system. It also requires technical support and advice in order to develop/strengthen the necessary national capacity for the successful and timely completion of the aforementioned task

In view of the expanding applications of radiation and nuclear activities in the fields of health, industry and food and agriculture, there is a recognized need for an effective regulatory framework and safety infrastructure, together with a competent national regulator, to ensure the desired level of safety. The emphasis would be on regulatory oversight functions that are commensurate with the country's ongoing and



future plans to expand the use of radiation and nuclear-based applications in different sectors.

There is also the issue of workplace monitoring and collecting and assessing data from workplaces, which is essential for safety and protection.

ACTIONS TAKEN

In order to plan and undertake the mutually-agreed strengthening of the national regulatory structure in an efficient and timely manner (especially in TSA-1, TSA-2 and TSA-3) and the radiation protection services in the country,

assistance was provided to Afghanistan on various fronts including:

- * The establishment and strengthening of the legislative and regulatory frameworks in a manner that is commensurate with the level of radiation use in Afghanistan;
- * The drafting and enactment of the Nuclear Energy Law and radiation safety regulations, rules and guidelines that control the licensing, use and inspection of radiation sources, techniques and applications, and which ensure that the National Regulatory Authority can discharge its mandated oversight functions;

- * The continued development of human resources, competencies and training programmes necessary for the sustainable delivery of radiation protection and control services in accordance with the licensing requirements of the regulatory framework;
- * The establishment of a national policy and strategy for education and training in radiation safety, in line with IAEA Safety Standards, to support the safe use of ionizing radiation and nuclear technologies;
- * The strengthening of personal dosimetry for measuring and recording radiation doses received by employees for the purposes of control of occupational exposure;
- * Assistance towards instrument testing, and calibration and certification services of radiation instruments;
- * The enhancement in quality assurance and calibration of X-ray and other imaging equipment to ensure that imaging equipment continues to be compliant with current standards;
- * The training and advice service for the radiation protection officers of licensed facilities, including advice on record keeping, design and shielding calculations for new or replacement installations, and management of radioactive waste; and
- * The establishment of training programmes at the national level to train groups of medical professionals, physicists, and technologists in various aspects of patient protection in diagnostic and interventional radiology.

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ACHIEVEMENTS

A Presidential Decree in April 2011 established the Afghan Atomic Energy High Commission (AAEHC) to be in charge of all national activities related to the peaceful use of nuclear energy, and to act as the National Regulatory Body. Based on this Decree, the head of the AAEHC is the President of Afghanistan. He appoints the Director General of the Executive and Technical Board of the AAEHC who is in charge of all nuclear activities across the country. Eleven Ministers serve as Board Members

Decree No. 461, issued in March 2014, gave the mandate to the Executive and Technical Board of the AAEHC to issue licenses and to conduct inspection of radiation practices and sources in the country. The Afghan Nuclear Law, which had been drafted by the AAEHC with the assistance of the IAEA, was translated into local languages and was approved by the parliament and issued through the National Gazette No.1182 on 15 November 2016.

The new law established a national regulatory body which is not involved in promotional activities and is in compliance with international standards. Based on this law, the Executive and Technical Board of the AAEHC became an independent agency called the Afghanistan Nuclear Agency. The Nuclear Agency consists of two independent bodies: the national regulatory body, which is in charge of monitoring and licensing of all atomic energy activities, and another body for promoting nuclear technology for sustainable development.

Taking into account the present level of use of radiation sources in Afghanistan, the regulatory body has the necessary mandate to carry out its functions. The current focus of the regulatory body is the development and/or updating of a complete set of radiation safety regulations, guides and standards that are based on the new nuclear law and which are necessary for the effective discharge of the regulator's oversight functions towards radiation facilities, radiation sources, radioactive wastes and related activities in accordance with the mandate of the National Regulatory Authority.

The IAEA is providing assistance in further enhancing the qualifications, skills and experience of the regulatory staff in the following areas: drafting and updating of safety regulations, guides and standards; licensing and authorization; inspection and enforcement; inventory of radioactive sources; and a system of notification and updating of the national register of radiation sources with special emphasis on the control of the export and import of radioactive sources, as well as the management of disused sealed radioactive sources (DSRS).



Afghanistan is well represented on the IAEA Board of Governors. (Photo: D. Calma/IAEA)

BANGLADESH

NUCLEAR TECHNOLOGIES FOR FOOD SECURITY



Photo: Ashrafal Haque Akash/Unsplash



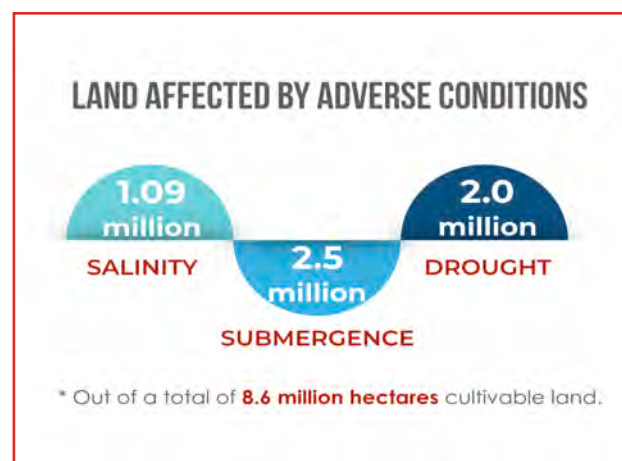
THE SITUATION

Bangladesh is on the road to rapid economic growth. Nevertheless, poverty, malnutrition, and food insecurity remain major challenges in the country.

Fragile ecosystems are big obstacles for agriculture in Bangladesh, negatively affecting the productivity of rice and other crops that are already prone to diseases and affected by salinity, submergence, drought, as well as inadequate soil/water/fertilizer management.

Climate change has additionally posed a serious threat to the food and nutritional security of Bangladesh. At the same time, cultivable lands are decreasing by 0.67% every year due to urbanization and industrialization. Most of the cultivable lands are planted with a single crop or left as fallow land.

For the past two decades cropping intensity in Bangladesh was less than 100%.



ACTIONS TAKEN

In looking for ways to protect the country's agriculture from the effects of climate change, Bangladesh Institute of Nuclear Agriculture (BINA) turned to nuclear technology-based solutions.

During the Green Revolution in the 70s, BINA began using induced mutations to improve existing high yielding crop varieties like the IR-

8, a green revolution variety developed by the International Rice Research Institute (IRRI).

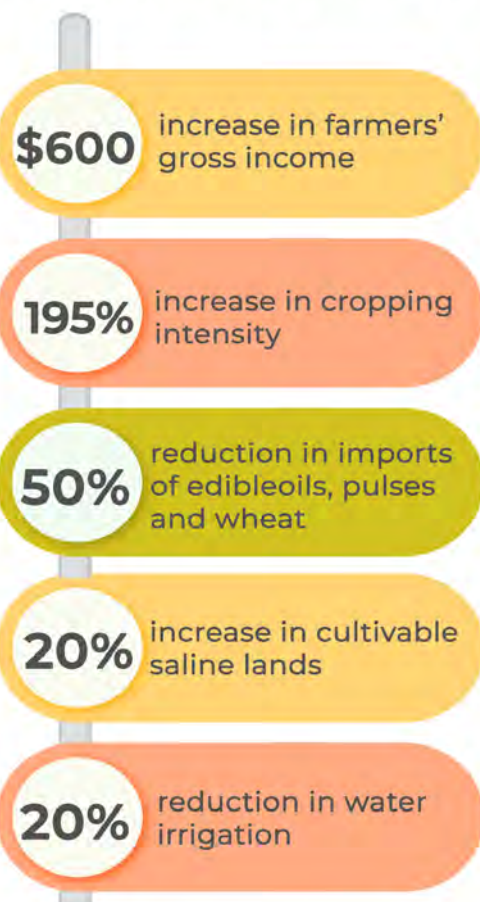
With the help of the IAEA, IR-8 was irradiated and resulted into two higher yielding rice varieties – the IRATOM-24 and IRATOM-38. These rice varieties were released to farmers in 1975.

But with the onset of global warming and climate change these rice varieties are no longer as productive. Consequently, Bangladesh urgently needed to develop new high-yielding varieties that are stress tolerant and mature quickly to enable multi-cropping.

Through IAEA technical cooperation projects and support from the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, BINA started using induced mutations and advanced techniques to develop short duration, high yielding and climate-smart crop varieties.

So far, BINA has already developed more than 60 mutant crop varieties with these characteristics.

BENEFITS FROM USING BINA MUTANT CROP VARIETIES



BINA has also developed several other high yielding and climate resilient crop varieties with support from the IAEA, the Food and Agriculture Organization of the United Nations (FAO), International Center for Agricultural Research in the Dry Areas (ICARDA), IRRI, and Bangladesh Atomic Energy Commission.

BINA also implemented a plant-soil-water management system to maximize agricultural productivity.

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ACHIEVEMENTS

So far BINA has developed 106 suitable high yielding varieties — 60 of which are mutant varieties — with different improved characteristics.

Among them are the following:

- * The short duration Binadhan-7 and Binadhan-16 rice varieties enable farmers to cultivate another crop in between harvests. This increases the income of farmers and helps to mitigate seasonal unemployment in the north-western part of Bangladesh.
- * The salt tolerant Binadhan-8 and Binadhan-10 rice varieties are now planted in 20% of total saline lands in Bangladesh, benefiting farmers economically.
- * The submergence tolerant Binadhan-11 and Binadhan-12 rice varieties have increased the rice yield in flood-prone areas.
- * The short duration Binadhan-14 irrigated rice variety has higher yield and is resistant to high temperatures (up to 36 degree centigrade). This rice variety can accommodate an additional crop in between two rice seasons, thus reducing import of edible oil, pulses and wheat by 50%. This variety also uses 20% less irrigation water.
- * The zinc enriched Binadhan-20 rice variety possesses 27.5 ppm zinc and 30 ppm iron and is popular among poor, malnourished farm families in Bangladesh.
- * The Binasarisa-9 and Binasarisa-10 varieties mature in 78-85 days. This makes it possible to plant rainfed season or irrigated winter season rice in-between harvests, thus increasing cropping intensity.
- * The Binamasur-5, -6 and -8 high yielding lentil varieties are tolerant to stemphyllum blight disease and capable of combating adverse effects of climate change.
- * Binadhan-19 and Binadhan-21 rice varieties can thrive through drought and are being cultivated in the uplands.
- * Salt tolerant wheat Binagom-1 and groundnut varieties like Binachinabadam-5, 6, 7, 8, 9 and 10 are widely cultivated in the saline areas of Bangladesh.

BINA has also been able to identify eight *rhizobial inocula* for fixing higher biological nitrogen in soils to increase the grain yield of bean, pulses and oil crops. All of these biofertilizers are environmentally friendly and affordable, and help increase grain yield of leguminous and oil crops from 20% to 150%.

BINA is also successfully using nuclear techniques in pest, soil and water management studies, nutrient uptake research, organic matter and crop residue studies to stop degradation of natural resources and preserve the environment.

Many of these technologies have gained much popularity among the farmers in Bangladesh. Irradiated seeds of rice, lentils, chickpeas, peanuts, mustard, sesame, soybean, jute, tomato and wheat are now widely planted across the country. They now account for about 8% of Bangladesh's crops, helping farmers improve their livelihoods.

BAHRAIN

DETERMINING PESTICIDE RESIDUES IN FOOD AND WATER



Photo: Bahrain Ministry of Health



improve the marketability of some of its food exports in the international market. Bahrain's Public Health Laboratories, therefore, needed to improve its capabilities – in terms of equipment and trained staff – to ensure the safety and quality of the country's food supply.

In this regard, Bahrain sought comprehensive IAEA cooperation in monitoring pesticides, contaminants and other toxic residues in food and water with the use of nuclear techniques.

ACTIONS TAKEN

An expert mission was carried out to train local experts on sampling and analytical techniques for determining the pesticide residue in food items.

The practical training involved staff of the Public Health Directorate including food control section inspectors and the public health laboratory chemists. They were given hands-on exercises on sampling methods, ways to determine adequate sample size, importance of fruit size, and on using adequate tools to perform accurate sampling. The training benefited both the Food Control Section and the Chemical Analysis Group in understanding adequate sampling procedures which directly affect the analytical results.

The application of analytical instruments for testing of food contaminants was further strengthened through an expert mission which took place from 7–11 January 2018.

The visiting expert gave lectures on method validation, particularly in pesticides, and supervised the analysis performed in the

THE SITUATION

Bahrain imports most of its food stuff from different countries. There are concerns that the imported food may be contaminated with banned pesticides such as dichlorodiphenyltrichloroethane (DDT) or a high dosage of permitted pesticides which adversely affect human health.

The use of toxic pesticides to manage pest problems is still a common practice around the world. Pesticides are used almost everywhere – not only in agriculture, but also in homes, parks, schools, buildings, forests, and roads. Pesticides also contaminate drinking water sources. In addition, pesticides can be found in the air we breathe, the food we eat, and the water we drink.

In Bahrain, the responsibility for imported agricultural food was transferred to the Ministry of Agriculture a few years ago, and pesticide analysis was done at a private laboratory.

Bahrain has made food safety a national priority, both to protect the health of its citizens and to



Photo: Bahrain Ministry of Health



A local market in Manama, Bahrain. (Photo: G.Masci/123RF.com)

laboratory using the QuEChERS and then LC-MS/MS methods (*see sidebar*).

In addition to training on multi-level calibration techniques, the expert also gave theoretical training on LC-MS/MS for use in pesticide analysis. This included tuning, method development, calibration and running the samples. Furthermore, they also trained on sample preparation, extraction and clean-up procedure, and on how to employ the QuEChERS method.

The previous laboratory practice was to analyze each type of pesticide separately. Now, the analysis of pesticides on LC-MS/MS can provide analytical data on organophosphorus, carbamates, and other non-organochlorine pesticides. This has increased the laboratory's capacity to perform more tests in a shorter amount of time.

At the same time, the procured instruments have helped in drastically decreasing sample preparation time. This, in turn, helped enhance the quality of homogenized samples and improved capacity building with respect to the analytical capability of the LC-MS/MS method.

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ACHIEVEMENTS

The laboratory is now using the more advanced QuEChERS method. This method has increased the testing rate to 10 samples a day compared to 1-2 samples every three days in the past. At the same time, the number of pesticides to be determined has been raised to approximately 160, which increased the laboratory's capability to analyze a wide range of matrices — fruit, vegetables, seeds, etc.

Other achievements include:

- * Support for the pesticide screening programme for two consecutive years;
- * Development of the skills and capabilities of chemists and health inspectors from the Ministry of Health and the Ministry of Agriculture through specialized training courses in the field of import and examination of imported and local agricultural samples;
- * Assistance in purchasing equipment needed by the laboratory to optimize the test results like gas chromatography-mass spectrometry (GC-MS)/MS auto-sampler, LC-MS/MS columns, food processors, Romer miller, ultrasound and QuEChERS kits enough for 500 samples;
- * Updating national requirements and standards to meet internationally accepted norms;
- * Assistance in the provision of laboratory test supplies to cover most pesticides used by agriculture in the country;
- * Provision of approximately 47 000 dinars from the country's budget for food testing;
- * Supporting the export checks of spices in the Kingdom of Bahrain, one of the most important exported commodities in Bahrain. According to 2018 statistics, the local spice production exceeded 431 tons /year. In the same year, the number of chemical tests, including pesticide residue and Mycotoxins tests reached 5517 tests with 12% unsatisfactory results;
- * Development of effective communication between the Ministry of Health and the Ministry of Agriculture and Municipal Affairs. For example, all insecticide residues are covered in public health laboratories and all results and statistics are sent to the Ministry of Agriculture, which can then take the necessary measures to protect the health of the consumer.

NOTE: QuEChERS is a solid phase extraction method for detection of pesticide residues in food. The name is a portmanteau word formed from “quick, easy, cheap, effective, rugged, and safe

LC-MS and LC-MS/MS are the combination of liquid chromatography (LC) with mass spectrometry (MS). MS/MS is the combination of two mass analyzers in one mass spec instrument.

BRUNEI DARUSSALAM

DEVELOPING RADIOTHERAPY TREATMENT AND NUCLEAR MEDICINE CAPABILITIES

THE SITUATION

The Vision 2035 and Health Strategy of the Ministry of Health of Brunei Darussalam underlines the need to further develop a comprehensive, national radiotherapy and nuclear medicine capabilities to address the growing occurrence of cancer-related diseases. Achieving this aim requires the further development of the Jerudong Park Medical Centre and the Cancer Centre in Brunei (TBCC). In 2012, the Government of Brunei Darussalam passed an order establishing a comprehensive cancer care facility, including a Radiotherapy and Nuclear Medicine Department.

In 2015, two linear accelerators (linacs), brachytherapy equipment, cyclotron, and nuclear tomographic imaging machines (PET-CT and SPECT-CT) were purchased. Initially, one radiation oncologist, three medical physicists and one radiation therapist were hired, and a few consultants were engaged on a visiting basis to establish the two departments. The installation of radiotherapy equipment was completed in 2015, and the nuclear medicine equipment was installed and commissioned in 2016. Radiotherapy services to complement diagnostic imaging services were already in place but regulatory infrastructure and radiation safety infrastructure were at the early stage of development.

Brunei Darussalam became a Member State of the IAEA in 2014 and it was able to get advice on setting up nuclear medicine and radiotherapy facilities, and to participate in various IAEA activities.



Photo: Hamid Naseer/Brunei Cancer Centre



ACTIONS TAKEN

With the assistance of IAEA experts under technical cooperation project BRU6001, Supporting the Establishment of Radiotherapy Services at the Brunei Cancer Centre, existing radiotherapy and dosimetry equipment was commissioned. Moreover, in order to ensure that the newly operational facility has the highest safety standards of radiation dose delivery, clinical protocols and quality control and assurance policies for the use of the LINACs, brachytherapy and stereotactic radiosurgery were established. One staff received fellowship training in medical physics. At the same time,

IAEA experts advised on further enhancing the quality of clinical medical physicists, who are important in ensuring the appropriate radiation dose for patients.

The work in the development of the radiotherapy services at the Brunei Cancer Centre continued in the 2018–2019 cycle under the framework of the project, Strengthening the Nuclear Medicine Department at the Brunei Cancer Centre (BRU6003). A nuclear medicine physician joined the Brunei Cancer Centre in late 2017 as a consultant. Successive efforts have been made since then to complete the nuclear medicine core team.



Photo: Hamid Naseer/Brunei Cancer Centre

Experts on nuclear physics and radiopharmacy evaluated the installed nuclear medicine equipment and processes for the in-house production of radiopharmaceuticals and imaging. During these missions, assessments on quality control and assurance of nuclear imaging equipment was carried out in order to ensure patient safety and radiation protection aspects. Satisfactory comments from IAEA experts were encouraging and helped to promote the nuclear medicine services in the country.

The review also looked at the radiopharmaceutical and clinical aspects of a Ga-68 generator; chemistry and labelling of octreotide and derivatives / prostate specific membrane antigen (PSMA), novel PET tracers, new radioisotopes for therapy; and clinical indications of non-FDG PET tracers in nuclear medicine. Efforts for the introduction of a quality management system has been started in the Nuclear Medicine Department in line with the IAEA Quality Management Audits in Nuclear Medicine Practices (QUANUM). An awareness programme on radiation safety measures in nuclear medicine and treatment was put in place for healthcare staff and the general public. TBCC has received and installed a Ga-68 generator and module provided by the IAEA in February 2020.

To extend nuclear imaging, Ga-68 PSMA and Ga-68 DOTATATE imaging was started. Training sessions related to Ga-68 imaging were carried

ACHIEVEMENTS

By the completion of the first project in December 2016, brachytherapy equipment had been installed and fully commissioned. Following the delivery of a Ga-68 generator in February 2020, Ga-68 PSMA and Ga-68 DOTATATE imaging were also started.

Lack of trained manpower was one of the limiting factors for increasing the patient services. Lectures and hands on training sessions by IAEA experts during the expert missions and national training sessions helped to train the medical physicists, technologists, nurses and radiopharmacy staff. Various university students also attended the training sessions which not only promoted nuclear medicine but also opened a new insight for career development.

Meetings and talks of IAEA experts with oncologists, radiologists, cardiologists and other medical specialists increased awareness about the utility of nuclear medicine and helped to increase the patient referral. Meetings with government officials in the Prime Minister's office and in the Ministry of Health helped to improve regulatory and radiation protection matters related to nuclear medicine.

In 2019, almost 800 patients had successfully undergone nuclear imaging and therapeutic procedures. The Nuclear Medicine Department of the Brunei Cancer Centre, catered to 259 cases in 2018 and the number increased to 800 cases in 2019.

The Brunei Cancer Centre is the first facility in Borneo Island providing comprehensive state-of-the-art nuclear medicine services including Ga-68 imaging and theranostics.

The launching of nuclear medicine diagnostic and therapeutic services in Brunei Darussalam is a landmark achievement. It has not only helped to improve oncological services, but its utility can be extended to managing patients with cardiac and neurological problems as well.

Brunei's Cancer Centre strengthened its Nuclear Medicine Department in 2019 with assistance from the IAEA, enabling 98% of the country's cancer patients to receive treatment locally.

Besides continuous support from the Ministry of Health and the Prime Minister's office, the IAEA also played a major role in developing this service by providing technical experts and opportunities for training.

out during installation and through IAEA expert missions, which helped nuclear medicine staff to perform imaging, ensuring patient safety and radiation protection. Almost 33 patients have undergone this scanning procedure within the first three months after the installation.

The IAEA also supported the development of radiation safety infrastructure and the

establishment of the regulatory system in the Safety, Health and Environment National Authority (SHENA) of Brunei Darussalam.

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Photo: IAEA



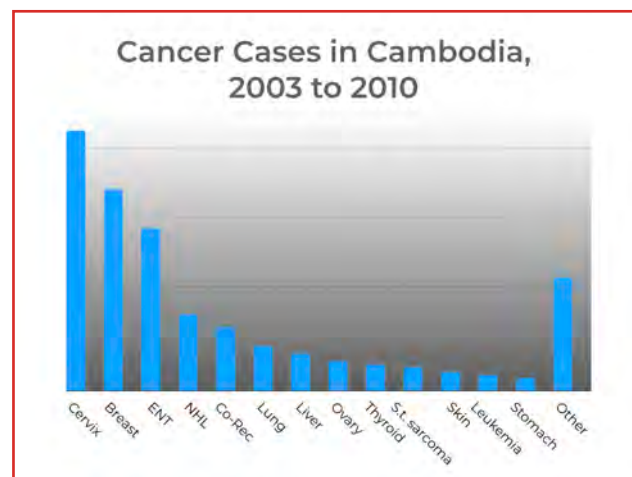
CAMBODIA

ESTABLISHMENT OF THE FIRST NATIONAL CANCER CENTRE

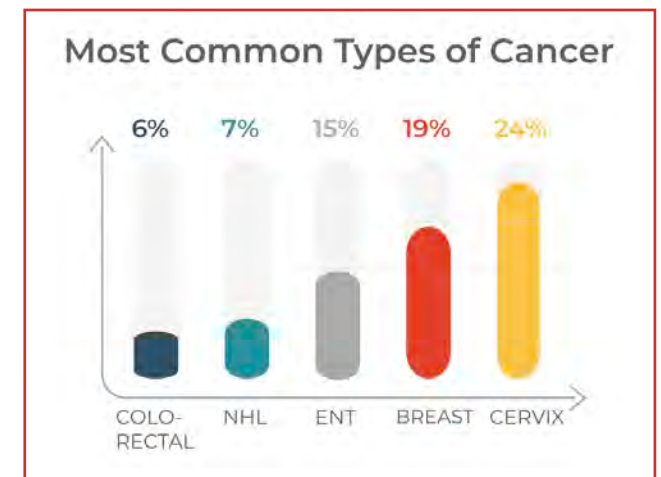
THE SITUATION

Cancer is a growing challenge in Cambodia, as in much of the developing world. Based on GLOBOCAN 2018 database, the Global Centre Observatory estimates Cambodia to have 15 362 cases of cancer per year with an estimated number of cancer deaths at 11 636. The five most common cancers are uterine cervix cancer, breast cancer, lung cancer, colorectal cancer and head and neck cancer.

Due to limited radiotherapy treatment facilities in Cambodia, cancer patients were referred to the only operational radiotherapy centre in the country, Khmer-Soviet Friendship Hospital (KSHF), which only had the capacity to treat 700 people in 2003. The number of annual



cases significantly increased to around 1700 cases registered and treated at KSHF in 2019. Alternatively, patients who could afford it could seek treatment in neighbouring countries. This left the vast majority of cancer sufferers with no access to proper treatment.



Moreover, Cambodia had no established national cancer registry previously. That meant that more than 70% of cancer sufferers were referred to oncologists only in the advanced or late stage of the disease, with very little to no chance for effective treatment.

ACTIONS TAKEN

In a sequence of Public Health Strategic Plans since 2003–2017, Cambodia and its Ministry of Health recognized the lack of trained professionals in the country, and committed to fighting non-communicable diseases including cancer. Cervical cancer is the most common form of cancer and can generally be cured with adequate teletherapy and brachytherapy.

In 2003, the Ministry of Health cooperated with two French non-governmental organizations – Doctors Without Borders and Oncologists Without Borders – to start a department of oncology at the Khmer-Soviet Friendship Hospital. The hospital was equipped with one cobalt machine, one simulator, and one low dose rate (LDR) brachytherapy unit. At that time, it was the only cancer treatment facility serving a population of 14.7 million people. It is still operational today. The cobalt machine has been replaced by a newly installed linear accelerator

funded under Phase 2 of the Public Health Strategic Plan.

In 2018, Cambodia finally established the National Cancer Center (NCC) on the premises of Calmette Hospital with support from two IAEA technical cooperation projects, KAM6001 and KAM6002. The projects started in 2012 and culminated with the inauguration of the NCC in January 2018. The new centre will significantly increase the country's capacity to fight the growing burden of cancer.

Cambodia dedicated € 36 million to ensure the centre's completion. The IAEA contributed over € 2 million in expertise related to its design, the commissioning of radiotherapy and nuclear medicine machines, and specialized staff training. The IAEA also provided additional equipment, including a gamma camera used for nuclear medicine imaging during body scans; a shielded fume hood to prepare radiopharmaceuticals, immobilization and mould room items; as well as radiation protection and dosimetry equipment.

Other international partners were also involved, particularly in building up human resources through on-site training, giving advice regarding building construction, machine selection, and technical assistance. Half of the centre's core staff participated in IAEA fellowships and trainings in regional hospitals and in Europe. In addition to acquiring technical skills, they also learned ways of dealing with patients – for example, how to create a good ambiance – which is an important aspect of cancer care.

Cambodia now plans to complete two more regional centres by 2025, through which 70% of the country's population will have access to cancer care.

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ACHIEVEMENTS

Prior to the cooperation with the IAEA, Calmette Hospital only had one radiation oncologist, who was the former director of the NCC. Today it has an entire team of highly trained staff (*see figure*).

The IAEA's technical cooperation support has been invaluable, both in enhancing technical skills, and in establishing ways of dealing with cancer patients to create a good ambiance during the treatment process.

Since the establishment of the NCC, approximately 150 patients have received radiation therapy (linac) and about 50 patients received brachytherapy.



After seeing the benefit and success of the National Cancer Centre and in response to further need, Cambodia's Ministry of Health is planning to establish two more regional cancer centres. One will be located in Siem Reap Province (northwestern part of

Cambodia) and the other one in Kratie Province (northeastern part of the country). Each regional centre will be equipped with one linac, one CT simulator, and one gamma camera. This plan is set to be completed by 2025.

CHINA

MUTANT GENE DISCOVERY FOR BETTER CROPS



Photo: Shutterstock



THE SITUATION

China has made great achievements in mutation breeding with the data reflecting more than 1000 mutant varieties developed and officially released by 2018. However, the precise description on the whole genome level for the specificity of different mutagens for gene mutation induction and the process of mutation occurrence remains unknown.

Major problems that were encountered include the following:

1. How to bring the full advantages of the nuclear irradiation technique in constructing nuclear irradiation-induced mutant libraries?
2. How to rapidly discover mutated allelic genes in large-scales for important characters in early generations?
3. How to dissect gene function for important characters in wheat and rice by means of mutated genes?

ACTIONS TAKEN

Under an IAEA national technical cooperation project, several activities were carried out to enhance the capabilities of Chinese laboratories in using nuclear irradiation techniques efficiently, rapidly mining mutant alleles and figuring out their functions. The project was entitled, Construction of nuclear radiation-induced mutant libraries and function analysis of mutated genes in wheat and rice (CRP5017). Activities under this project included scientific visits, training courses and fellowships, among others.

The Institute of Crop Sciences, Chinese Academy of Agricultural Sciences (ICS, CAAS) and Zhejiang University participated in the project which ran from 2007 until 2010.

Before the project started, only gamma rays were used for crop mutant development in China. In 2018, through scientific visits arranged under the project, senior Chinese researchers visited gamma-field and heavy ion beam irradiation facilities in Japan. There they were able to observe the ion

beam characteristics and its biological effects in crop mutation induction.

This eventually led to the promotion of simulated space mutagens development in China, among others. These newly developed mutagens were later used in the development of China's crop mutant libraries.

Actions were also taken to solve the bottleneck on mutant allele mining and mutation gene function analysis. Through the CRP5017 project, two sets of Li-Cor 4300 DNA Analyzer— a high throughput equipment for large scale mutant allele mining by targeting induced local lesions in genomes (TILLING) approach — were donated to the Institute of Crop Sciences and Zhejiang University in 2008 and 2009, respectively.

At the same time, a senior Chinese expert went on a scientific visit to the University of Bologna, Italy to investigate the application of TILLING in crops. Then in 2009, two fellows from China were trained on TILLING at the IAEA's plant breeding laboratory at Seibersdorf and at Rothamsted Research in the United Kingdom.

At these training courses, the scientists learned how to use the donated equipment to identify mutant alleles. Upon returning to China, they started to establish the TILLING platform in their home laboratories using the skills they had gained. To help speed up the process, experts from the IAEA were invited to give technical guidance.

Finally in 2011, a stable TILLING platform was established at the Institute of Crop Sciences and used for targeted mutation allele identification and gene function analysis.

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ACHIEVEMENTS

Enhanced human capabilities on basic research

Chinese scientists established a TILLING platform at ICS, CAAS after their IAEA training. The capabilities of mining mutant alleles in local laboratories had been enhanced significantly, and the mutated alleles were further used for gene function elucidation.

In 2018, by using the equipment and TILLING approach, the scientists had published over 20 peer-reviewed research papers in *Frontiers in Plant Science*, *BMC Genomics* and other scientific journals, and trained over 150 researchers from national institutions and Asia Pacific region.

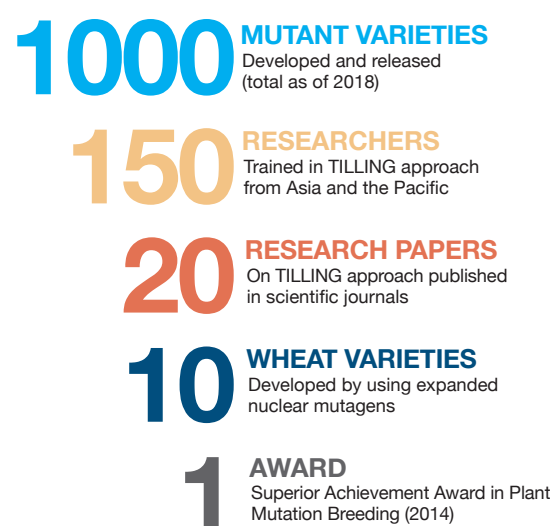
Improved crop varieties benefit local farmers

By using the expanded nuclear mutagens, ICS, CAAS established a broad spectrum mutant library and developed over 10 mutant wheat varieties such as Hangmai 247, Hangmai 2566, Luyuan 502. Among these, Luyuan 502 was nationally released in 2011, and by 2017, had been planted on over 3.6 million hectares in China. Since then, it has become the second most widely planted wheat mutant variety in China, and from 2012 to 2017, helped farmers gain 948 million US dollars in additional income.

Hangmai 247 is an environment-friendly national wheat variety with improved drought and lodging resistance. It was released in 2016.

In September 2014, the Joint FAO/IAEA Division in Nuclear Techniques in Food and Agriculture honoured the Wheat Mutation Breeding Team of ICS, CAAS with the Superior Achievement Award in Plant Mutation Breeding.

ACHIEVEMENTS BY NUMBERS



INDONESIA

ACHIEVING SELF-SUFFICIENCY IN SOYBEAN PRODUCTION

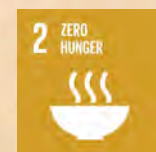


Photo: R. Quevenco

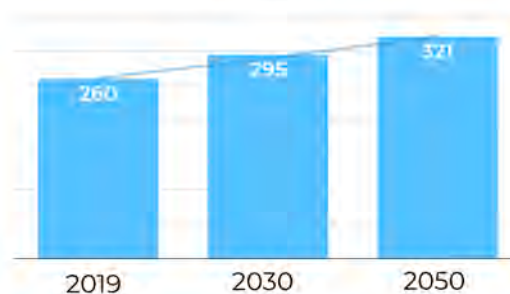
THE SITUATION

With an annual growth rate of 1.9 per cent, Indonesia's population is predicted to increase from 260 million in 2019 to 295 million by 2030 and then to 321 million by the year 2050. Indonesia is also facing the problem of diminishing agricultural land and erratic changes in climate that have had a negative impact on food production.

Soybean is the main source of vegetable protein in Indonesia, but soybean farming is beset by low productivity and high consumption. Average production of national, elite soybean varieties is just 1.6 tonnes per hectare. The total land cultivated with soybean has also declined due to strong competition from other, more profitable cash crops.

In Indonesia, soybean is used both as animal feed and as processed food for human

Indonesia's Population Growth Trend (Millions)



consumption, and domestic production cannot meet existing demand. From 2010 to 2014, Indonesia imported some 1.7-2.1 million tonnes of soybean. This represents about 65% of all soybean consumed in the country.

To reduce soybean imports, Indonesia has launched a government programme to achieve soybean self-sufficiency in 2020. This challenging task requires the government's hard

work, and the support of various parties such as farmers, traders, agricultural counseling workers, and other stakeholders.

There are several avenues of action they can take. Indonesia has around 7 to 8 million hectares of rice fields. Farmers could utilize these lands by growing soybean in-between two rice harvests per year. In addition, soybean can be grown in idle lands.

Another option which Indonesia has pursued is to plant improved crop varieties developed through radiation mutation techniques.

ACTIONS TAKEN

To meet the increasing demand for food, Indonesia made efforts to improve food production through the use of superior crop varieties, among others. These improved plant varieties were developed through Indonesia's

plant mutation breeding programme. The new varieties were chosen on the basis of higher productivity, disease resistance and adaptability to various land conditions.

The National Nuclear Energy Agency of Indonesia (BATAN) first started using radiation mutation technique in 1972, using gamma rays produced by the Cobalt-60 source at BATAN irradiator facility. As early as 1997, Indonesia also began cooperating with the IAEA Department of Technical Cooperation and the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture in the field of plant breeding.

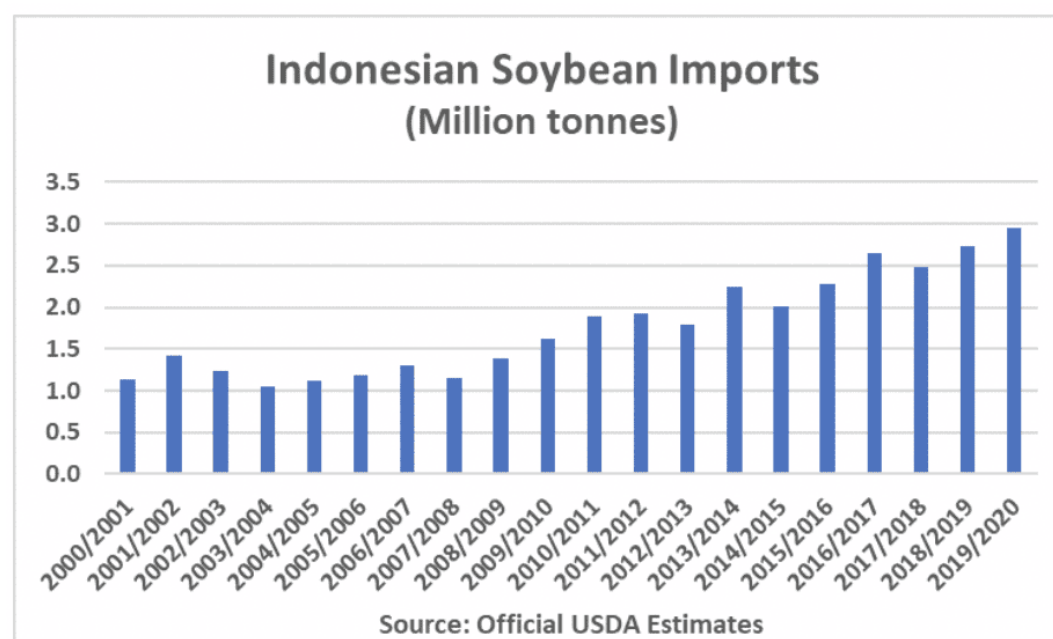
Indonesia's first technical cooperation project with the IAEA was on *in vitro* mutation techniques, with the objective of helping Indonesia develop improved cultivars of banana that are resistant to fusarium wilt.

The first gamma irradiation project was initiated in 1999 with the aim to develop new induced mutant varieties of cut flowers with desirable traits such as pest and disease resistance and novelty in flower colour, shape, size and fragrance.

Scientists at BATAN's research centre received state-of-the-art equipment, extensive training in nuclear techniques, and support from experts through IAEA coordinated research and technical cooperation projects.

This laid the foundation for Indonesia's plant mutation breeding programme.

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ACHIEVEMENTS

Twelve soybean mutant varieties have been released by BATAN through its plant mutation breeding programme. The new varieties are bred using irradiation and selected based on their improved characteristics such as higher yields, shorter cultivation time or resistance to diseases and the effects of climate change.

Once ready, seeds for these new crops are multiplied and then made available to the farmers.

BATAN's most successful soybean variety is MUTIARA 1, which has a high yield (4.1 tonnes per hectare), big grain size (24.3 grams) and is tolerant to leaf spot and pod stem borer. Klemuning 1 and Klemuning 2, the last two varieties developed, have the characteristics of having high yield potential on dry land. They were officially registered and released by the Ministry of Agriculture in 2019.

These improved soybean varieties have been disseminated to Indonesian farmers, along with on-farm support. Work continues to maintain the seed source of mutant varieties to maintain the availability of national soybean seeds.

To further support Indonesia's soybean self-sufficiency programme, the Ministry of Agriculture declared 2018 as the year of soybeans. The aim was to encourage the expansion of new planting areas, strengthen the soybean seed production system, pest and disease control, and to develop a new inter cropping system.

The adoption and enforcement of a national policy on intensification of soybean production at the national and provincial levels is still ongoing.

ISLAMIC REPUBLIC OF IRAN

THIRTY-YEAR JOURNEY TO RADIOPHARMACEUTICAL SUPPLIER STATUS



ACTIONS TAKEN

To reach its goal of becoming a producer of medical radioisotopes and radiopharmaceuticals, Iran had to go through several stages (*see figure*).

The government's commitment to use radiation applications and nuclear energy for the welfare of the people has led to the establishment of several major facilities in the country. These include research reactors, particle accelerators, and several other infrastructures that were crucial in helping Iran reach its goal. In addition, training a selected number of staff has provided Iran with motivated and highly qualified experts who are able to use the laboratories and facilities in the most efficient way.

Through the IAEA technical cooperation programme, emphasis was given especially to knowledge transfer and capacity building,

THE SITUATION

Since joining the IAEA in 1959, Iran has been constantly working in the peaceful uses of atomic energy, especially in the field of radiation applications. The country's strong desire to benefit from the peaceful uses of atomic energy resulted in the establishment of the Atomic Energy Organization of Iran (AEOI) in 1974.

One of AEOI's highest priority was to develop and enhance Iran's capabilities to provide services to patients through the indigenous

production of medical radioisotopes and radiopharmaceuticals.

In 1989, there were less than 10 nuclear medical centres in Iran that were operated by licenced nuclear medicine specialists.

At this time, Iran's 5 megawatt research reactor was already in operation, together with some peripheral laboratories. But production facilities for technetium-99m (TC-99m) generator and iodine-131 (I-131) therapeutic radioisotope were non-existent, and there was a lack of qualified staff and experts.



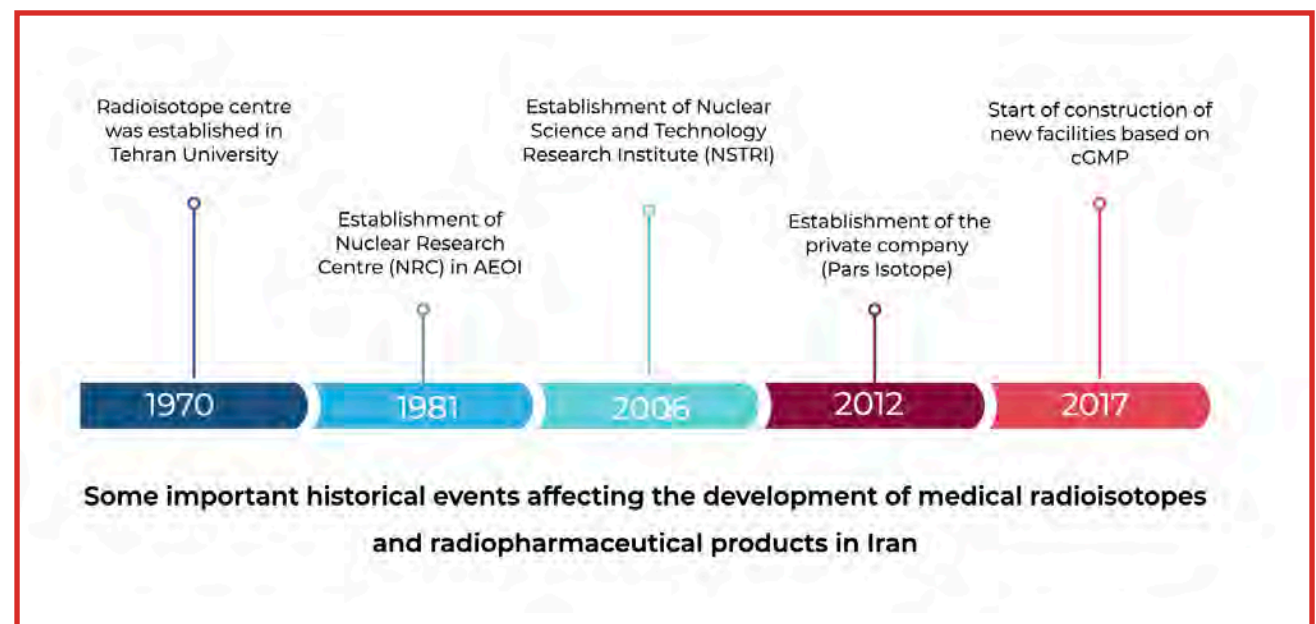
FACTS AND ISSUES TAKEN INTO CONSIDERATION

- * Commitment of the government, national organizations and management;
- * Training of personnel and the staff (human resource capacity building);
- * Hiring a motivated, skillful and highly educated management team and staff;
- * Establishing suitable organizations such as Nuclear Research Centre (NRC), Nuclear Science and Technology Research Institute (NSTRI), and private companies (such as the Pars Isotope Company);
- * Developing, establishing and expanding the required infrastructures;
- * Standardizing the production processes;
- * Connecting with the best radioisotope suppliers all over the world;
- * Benefiting from international experiences;
- * Availability of Tehran Research Reactor (TRR) for production of reactor-based radioisotopes;
- * Establishment of 30 MeV cyclotron (Cyclone-30) for production of cyclotron-based radioisotopes;
- * Using national industrial capacities for production of required equipment;
- * Implementation of a national project for development of 15 important radiopharmaceuticals for nuclear medical centers in 3 years;
- * Implementation of bilateral production and development projects with foreign companies (Lu-177 radiopharmaceuticals, Re-188 radiopharmaceuticals, etc.);
- * Good collaboration with foreign institutes and equipment manufacturers all over the world;
- * Establishing graduate level studies in the country via MSc and PhD university programmes in nuclear engineering, medical physics, nuclear medicine and radiopharmacy;
- * Working closely with the IAEA through its technical cooperation programme.

as well as collaboration with several national and international parties. This enabled Iran to qualitatively and quantitatively develop its programme on the peaceful uses of atomic energy in a wide range of applications, particularly in the health sector.

For Iran, the most important issues in this journey were the following:

- * identifying the real needs and demands of the society;
- * good understanding of the gaps; and
- * good management of the resources to fill the identified gaps.



IAEA technical cooperation projects directly related to the development of medical radioisotopes and radiopharmaceuticals in chronological order from 1975

Project Number	Title	Objective	Year Approved	Year Completed
IRA2002	Quality control of isotopes	Establishment of a quality control unit to complete the production of radioisotopes for medical use	1975	1982
IRA2004	Radioisotope production	To extend the potential of the radiopharmaceutical production in the Islamic Republic of Iran by ensuring strict quality control.	1982	1993
IRA2003	Quality control of isotopes	To establish regular production and quality control of radioisotopes/ pharmaceuticals	1983	1986
IRA2005	Development of RIA Kits	To establish a program of indigenous production of high-quality radioimmunoassay (RIA) reagents and kits	1993	1998
IRA4021	Radionuclide Production with Cyclotron	To set up radiochemical facilities and techniques for the local cyclotron production of radionuclides for medical purposes	1993	1995
IRA4023	Cyclotron Production of Radionuclides	To expand the utilization of cyclotron beam lines for R&D and production of medical radioisotopes	1995	2000
IRA4026	Production of Radiation Sources for Medical Application	To develop laboratory facilities for production and after-loading of radiation sources for medical application	1997	1999
IRA4031	Cyclotron Production of Radionuclides for Medical Use	To consolidate and expand the current radionuclide production programme to include F-18 and I-123 based radiopharmaceuticals	1999	2001
IRA4030	Production of Miniature Sealed Sources for Brachytherapy	To extend the range of locally produced sealed sources to miniature sources for application in brachytherapy	1999	2001
IRA4032	Cyclotron Production of Palladium-103 and Cobalt-57	To extend the range of cyclotron-produced radionuclides to meet the demand in the national healthcare and industrial sectors.	2001	2005
IRA2006	Developing Technetium-99m Labelled Radiopharmaceutical Kits Based on Monoclonal Antibodies and Peptides	To develop and locally produce quality kits for preparing Tc-99m labelled radiopharmaceuticals based on monoclonal antibodies and peptides for imaging different types of tumours	2001	2009
IRA2007	Development and Enhancement of Radiopharmaceuticals in Accordance with Good Manufacturing Practices	To improve the overall capacity and standardize production protocols to manufacture radiopharmaceutical products, in accordance with good manufacturing practices (GMP), for distribution to the national nuclear medicine community.	2005	2010
IRA2008	Production, Development and Application of Radiation Sources and Radiopharmaceuticals for Radiotherapy and Targeted Cancer Therapy	To prepare therapeutic sources, radio colloid particles and radiopharmaceuticals for cancer treatment	2007	2013
IRA2009	Supporting the Development of Radiopharmaceuticals for Diagnosis and Therapy of Cancer and the Manufacture of Radioactive Sources for Brachytherapy	To prepare sealed sources and therapeutic radiopharmaceuticals for cancer treatment.	2009	2015
IRA2010	Supporting the Application of Therapeutic Radiopharmaceuticals in the Nuclear Medicine Centres and the Development of QA/Qc and QMS in Therapeutic Radiopharmaceutical Applications	To use quality assured therapeutic radiopharmaceuticals for the management of cancer and radiosynovectomy.	2009	2015
IRA6009	Developing Therapeutic Radiopharmaceuticals and Brachytherapy Products for Cancer Treatment and Radioimmunoassay Diagnostic Kits	To enhance the national capacity for production of radio diagnostic and radio therapeutic agents for nuclear medicine and brachytherapy in order to meet the local demand.	2014	Active
IRA6010	Enhancing Cancer Therapy through Development of Radiotherapy and Therapeutic Radiopharmaceutical Products	To enhance the national capacity for production of radio diagnostic and radio therapeutic agents for nuclear medicine and brachytherapy in order to meet the local demand.	2016	Active
IRA6011	Promoting Cancer Treatment Quality Using Radiation Through the Development of Radiotherapy Products and Strengthening Quality Assurance in Radiotherapy Procedures	To enhance the national capacity for production of radio diagnostic and radio therapeutic agents for nuclear medicine and brachytherapy in order to meet the local demand.	2018	Active

ACHIEVEMENTS

Iran is now able to meet all of its national radiopharmaceuticals demand. Iran is also one of the few countries recognized as a supplier of radiopharmaceuticals exporting its product to other countries.

In 2016, AEOI announced that 40 types of radiopharmaceuticals were currently being produced inside Iran and are being exported to a number of countries.

The government's strong commitment and support, the assistance of the IAEA and the involvement of other national and international organizations, as well as the effective efforts of the motivated managers and qualified technical staff have led Iran to a point where the large-scale production of several radiopharmaceuticals is managed by the private sector, while the research on the production of new

Comparison of Iran's status, 1989 and 2019

	1989	2019
Number of nuclear medical centres	<10	186
Number of PET centres	0	5
Number of nuclear medicine specialists	<10	200
Weekly use of Tc-99m generators	0	350
Weekly use of I-131 (Ci)	0	50

radiopharmaceuticals is mainly the responsibility of the Nuclear Science and Technology Research Institute as a governmental organization.

In continuation of this journey, radiopharmaceuticals production has always been focused on enhancing product quality to meet international standards. In this regard, a comprehensive and large-scale

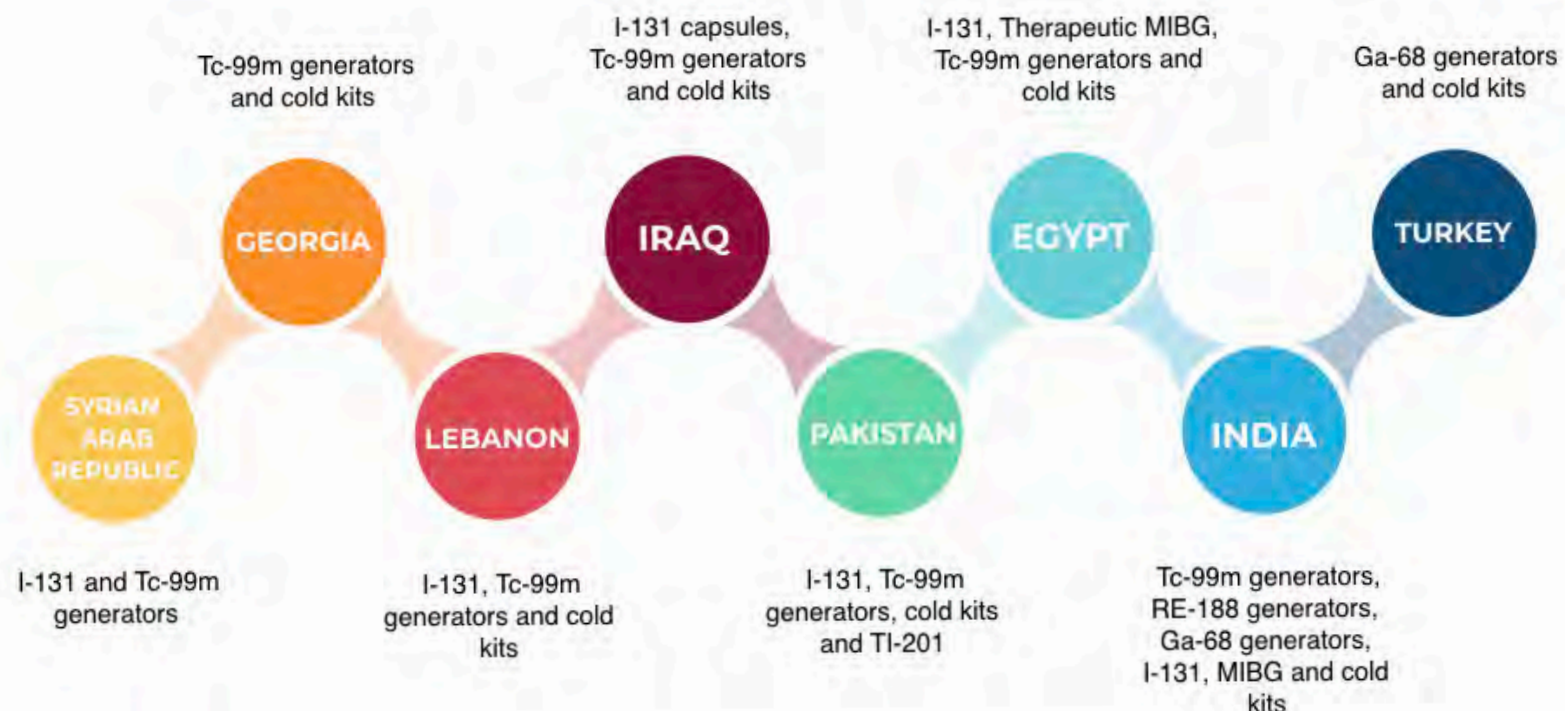
Recent products based on International standards

- ✓ Tc-99m generators and related cold kits.
- ✓ Main therapeutic radioisotopes such as I-131 and P-32
- ✓ New Tc99-m cold kits (Peptides), fluorodeoxyglucose (FDG), new therapeutic radioisotopes such as Lu177- and Y90-

radiopharmaceuticals production facility, in accordance with current good manufacturing processes (CGMP), is presently under construction in Tehran.

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Radiopharmaceuticals and Radioisotope Products Exported to Other Countries



IRAQ

LOOKING AHEAD TO THE FUTURE

THE SITUATION

The Iraq war that started in 2003 had a major impact on the nuclear infrastructure in the country. Many facilities and sites from the former Iraqi nuclear programme were destroyed. As a consequence, there was considerable damage to equipment and materials within these facilities, some of which are radioactively contaminated.

There is a strong need to perform decommissioning and bring these sites under regulatory control in accordance with the IAEA's Basic Safety Standards in order to ensure the safety of both public and environment.

Iraq's first Country Programme Framework (CPF) with the IAEA was signed on 18 September 2012 for the period 2012–2017. The CPF served as the frame of reference for the medium-term planning of technical cooperation between Iraq and the IAEA. It identified priority areas where the

Iraq signed its first Country Programme Framework with the IAEA in September 2012 (Photo: IAEA).



Photo: Rasoul Ali/Shutterstock

transfer of nuclear technology can be directed to support national development goals.

Besides improving the nuclear safety infrastructure, the development of climate smart agriculture and the rehabilitation of hospitals, in particular for the diagnosis and treatment of cancer, were identified as the two other priority sectors for Iraq.

With the help of the IAEA, Iraq has developed a comprehensive strategy to systematically address the infrastructural gaps in these priority areas, contributing to the socio-economic advancement of the country.

ACTIONS TAKEN

Under TC projects IRQ9007 and IRQ9011 (Decommissioning and Remediation of Former Nuclear Facilities and Sites, Phase 2), the IAEA provided training and technical support for the preparation of the plans and documents required for the decommissioning and remediation of high-risk facilities, including the IRT-5000 Reactor.

The capacity of regulatory oversight in terms of authorization and inspection of radiation sources was enhanced through the training of professionals, and the procurement of necessary equipment.

List of activities implemented for the years 2009–2018 between IAEA and Iraq for national, regional and interregional projects.

Year	Training Courses	Meetings	Workshops	Scientific Visits	Fellowships	Conferences	Total
2009	32	14	2	13	9	15	85
2010	18	9	6	10	9	9	61
2011	42	39	5	4	10	7	107
2012	16	28	9	7	1	3	64
2013	17	20	9	-	4	1	51
2014	30	28	23	2	5	8	96
2015	10	21	14	1	7	4	57
2016	16	22	16	2	5	2	63
2017	22	14	18	7	7	2	70
2018	10	18	16	1	3	8	56

With regards to climate smart agriculture, the IAEA provided Iraq with support through several TC projects to apply mutation breeding techniques to develop newer crop varieties that are resistant to drought and climate change phenomenon.

Technical support was also provided to Iraq under IRQ5018 (Using Fallout Radionuclides and Stable Isotope Techniques to Assess Soil Quality and Dust Production for Enhanced Agricultural Land Productivity) and IRQ5019 (Utilizing Nuclear Techniques to Increase Water Use Efficiency and to Improve Soil Management of Degraded Soil) on the use of stable nitrogen isotopes to assess, improve and optimize soil quality with respect to moisture and fertilizer content, thereby increasing the crop yield. More than 20 fellows were trained on advanced nuclear techniques in food and agriculture and in the use of stable nitrogen isotopes under these projects.

In the human health sector, the IAEA assisted Iraq with the rehabilitation of medical centres, improving the infrastructure and quality of medical treatment. Since 2012, successive national projects have continued to support capacity building in nuclear medicine departments, particularly at the Al-Amal

hospital, Baghdad, as well as the production of radiopharmaceuticals in the country.

A comprehensive ImpACT review jointly conducted by IAEA, the World Health Organization and the International Agency for Research on Cancer (IARC) is planned for 2021.

The review will assess Iraq's cancer control capacities and needs, and identify the priority interventions needed to effectively respond to the country's cancer burden.

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ACHIEVEMENTS

Over the years, with IAEA support, Iraq has made good progress in developing decommissioning and remediation workplans for the high-risk facilities. As a last step in the life cycle of a nuclear facility, the work on decontamination, dismantling and removal of structures is moving well with gradual and sustained progress.

A new drought-tolerant wheat variety developed in Iraq with the support of the IAEA and the Food and Agriculture Organization of the United Nations (FAO) has increased yields four-fold. This mutant variety now accounts for close to two thirds of all the wheat produced in the country.

The technical support provided to Iraq through successive TC projects has significantly improved the diagnostic nuclear medicine and radiotherapy infrastructure in the country.

Besides operationalizing some diagnostic equipment at the national cancer centre in Baghdad, the advanced training provided has led to improvement in the quality of the treatment.

ISRAEL

STRENGTHENING EDUCATION AND TRAINING IN RADIATION PROTECTION

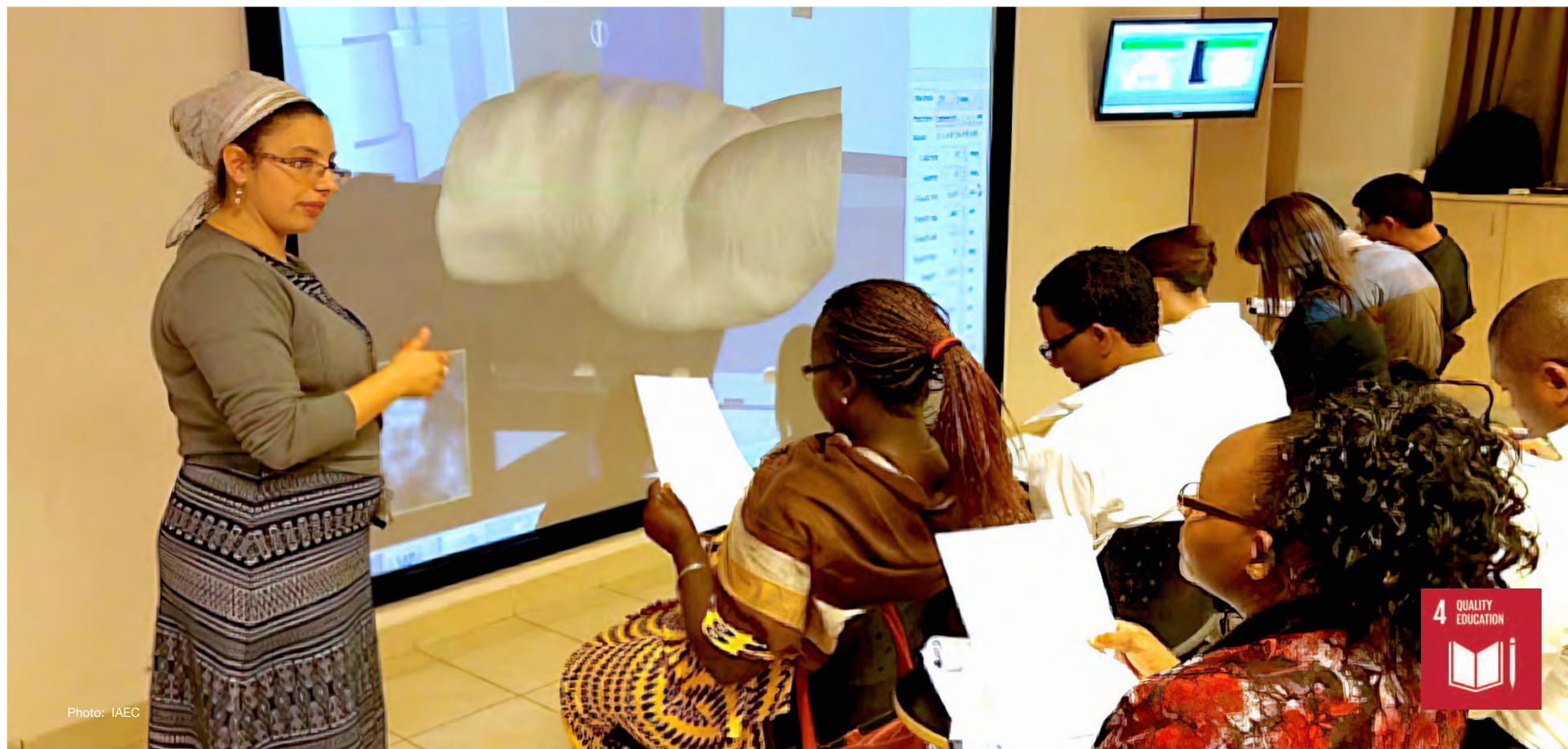


Photo: IAEA

THE SITUATION

Israel is a founding member of the IAEA, having joined the Agency in 1957. Its previous and current Country Programme Framework (CPF) agreements with the IAEA underline the importance of strengthening education and training in the field of radiation and nuclear safety and place it among Israel's top priorities.

The wide use of nuclear technology in Israel means that building capacity in the field of radiation protection is very important. Focusing on radiation protection includes the training of radiation protection experts, both from the

regulatory authorities as well as from various institutions dealing with radioactive materials.

Israel is fully aware of the necessity to build capability in different areas of radiation protection and to train and educate young scientists and engineers (the next generation) in the field. It aims, as well, to train new instructors in the Schools of Radiation Protection of the Israel Atomic Energy Commission (IAEC).

Israel has also identified the need to build capacity in radiation protection for all stakeholders. These stakeholders include the IAEC's Nuclear Licensing and Safety Office, the IAEC Schools of Radiation Protection,

the Ministry of Environmental Protection, the Ministry of Health, the Ministry of Labour and Social Affairs and the Ministry of Transportation.



A delegation from Israel pose with IAEA Deputy Director General Dazhu Yang and TC staff during the signing of Israel's Country Programme Framework for 2018-2023 on 18 September 2018 (Photo: IAEA).

ACTIONS TAKEN

The IAEA supported Israel under two technical cooperation projects ISR9008 (Improving and Strengthening Radiation Protection Education and Training, 2014–2018), and ISR9011 (Improving and Strengthening Radiation Protection Education and Training – Continuation, 2016–2019).

Under ISR9008, an education and training appraisal (EduTA) mission on radiation protection and the safety of radiation sources was conducted in Israel from 4–7 May 2015. The mission carried out a detailed appraisal of the status of the provisions for education and training in radiation protection and the safety of radiation sources. It also identified areas in education and training where the provisions could be improved to meet IAEA safety standards, the country’s national education and training needs, as well as industry best practices.

The EduTA mission made recommendations to further improve the legal and regulatory framework, and to develop a national strategy for education and training. Based on the mission’s recommendations, an action plan



The EduTA mission team members with Israeli counterparts (Photo: IAEA).

was developed and implemented to further strengthen the legal and regulatory framework for education and training in radiation protection and safety, including occupational and medical exposure.

Eleven fellows were trained on various aspects of radiation protection and in the safety of radiation sources under the ISR9008 and ISR9011 projects to develop a national team with strong knowledge and skills on radiation protection to implement the action plan.

Radiation protection in medical exposure was supported under TC Project ISR6023 (Strengthening Capacity Building and Improving Quality Assurance in Radiotherapy). The project implemented a quality assurance review at radiotherapy centres and supported the development of a simulator classroom for the National Centre for Radiotherapy Training.

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ACHIEVEMENTS

Capacity acquired through the TC projects enabled local professionals to enhance their knowledge and know-how for continuous self-training abilities for education and training in radiation protection in Israel.

The establishment of the National Centre for Radiotherapy Training as an innovative centre provides the most up-to-date CME (Continuous Medical Education) for all the radiotherapy professions and includes a wide variety of courses and training programmes in the field of radiotherapy. The centre is equipped with a virtual environment treatment room, workstations equipped with a radiation

oncology system and statistical software and a complete classroom management system.

The Mission Statement of the training centre states that: “The national school of radiotherapy exists to ensure the attainment of a standard of excellence in Radiation Oncology practices, through an innovative, dynamic learning environment, rich with simulation and a “hands on” approach with an emphasis on patient safety and compassion”

The centre has hosted many national and regional training courses for medical professionals, with the latest on accident prevention in radiation therapy that was held in 2019.

JORDAN

THE LIGHT OF SESAME: A DREAM BECOMES REALITY



Photo: D. Calma/IAEA



THE SITUATION

The idea was first raised by Pakistani physicist and Nobel Laureate Abdus Salam in the 1980s: a synchrotron light source research facility that would enable scientific and technical collaboration among countries in the Middle East region. Two decades later that idea has become a reality in the “light” of SESAME, the Synchrotron light for Experimental Science and Applications in the Middle East.

The Middle East as a whole was lacking a research facility that was ideal for building regional scientific know-how and for promoting scientific and technical collaboration with international counterparts. Synchrotron light sources are such ideal facilities.

But for SESAME, the journey from idea to reality was a long one that was often plagued with setbacks and challenges, mostly financial and political.

The financial challenge lies mainly in the fact that a facility such as SESAME consumes a significant amount of electricity: up to US \$300 000 in electricity bill per month. The political challenge was in bringing countries from the Middle East — whose political interrelations are sensitive — together in a project that had a wide regional and international impact.

ACTIONS TAKEN

SESAME’s journey lasted more than twenty years before it became a reality. In May 2017, an official inauguration took place and SESAME opened its doors to the world.

In July 2018, the first SESAME users from the Middle East started coming into SESAME and the first experiments were conducted. This has brought together scientists who come from countries which — despite their political differences — would sit on the same table to discuss only one thing, science.



The SESAME Facility in Al Balqa, Jordan. (Photo: SESAME)

SESAME Member States have contributed to its annual running budget since its establishment. The capital budget to construct the machine came from three main SESAME Member States namely Israel, Jordan and Turkey.

While the European Union (EU) contributed to funding a new Storage Ring, Solar Power Plant and laboratories, the Ministry of Higher

Number of experimental proposals received for the three calls

	Call 0		Call 1		Call 2		
	Deadline 15 March 2017		Deadline 25 Oct 2018		Deadline 27 January 2020		
	XAFS/XRF	IR	XAFS/XRF	IR	XAFS/XRF	IR	MS
Belgium						1	
Colombia		1					
Cyprus	1						
Egypt	6	2	13	17	11	21	2
France		1					
Germany			1	1			
Iran, Islamic Rep. of	2	3	8	4	12	13	9
Israel			4		3	1	
Italy	1	1	2		2	1	1
Jordan	2	2	6	9	5	8	3
Kenya	2				1		
Malta						1	
Mexico			1				
Pakistan	7	4	15	5	7	4	4
Palestine		1			5	3	3
Qatar					1		
South Africa					1		
Sweden	1						
Turkey	14		9	3	12	3	2
United Kingdom						1	
	36	19	60	43	64	63	24
	55		103		151		

Education and Science in Italy donated funds for the procurement of the Radio Frequency (RF) accelerator cavities and SESAME's new, modern guest house. These financial contributions helped bring the project to fruition and showed to the world that SESAME is a great success story of science diplomacy.

Money was and is still SESAME's greatest challenge. Several donors have invested in SESAME through financial support. They include the United Nations Educational, Scientific and Cultural Organization (UNESCO), the European Organization for Nuclear Research (CERN) and the IAEA. Other donors, including France, Germany, Switzerland, UK and the USA, have

donated equipment and expertise. Jordan, for its part, offered the land and paid for the construction of SESAME's building.

Deserving special mention are the staff of SESAME. At the start, many of them did not have the required expertise. Nonetheless, they successfully brought the machine into operation to its full energy of 2.5 GeV and demonstrated their commitment and great technical competence.

In 2006, IAEA signed a Memorandum of Understanding (MOU) with SESAME that set a framework for future cooperation between the two organizations. In line with this MOU, the

IAEA continues to support the human resource development for the construction and safe operation of SESAME.

ACHIEVEMENTS

Kicked off by a German injector donated from Bessy I and with continuous support from UNESCO, EU, the IAEA and individual countries, SESAME started hosting scientists, researchers/users in July 2018.

Today, SESAME represents the first synchrotron light source in the Middle East, with three operational beamlines. These are the x-ray absorption fine structure and x-ray fluorescence (XAFS/XRF) beamline; the infrared (IR) beamline; and a material science (MS) beamline, which started operations in 2020.

SESAME now also trains researchers from the region in advanced synchrotron technology, helping them raise their scientific skills to be at par with those of their counterparts worldwide. Additionally, by receiving and training researchers from Africa, as well as Asia and the Pacific, on its newly established light source, SESAME is paving the way for other regions who lack such a facility to possibly have their own synchrotron light source in the future. The table on the left shows the increasing interest among scientists from the region and beyond to use the light of SESAME.

Since February 2019, SESAME became the world's first accelerator powered solely by renewable energy, adding one more milestone to its journey of success. SESAME has proven and continues to show the world that science is a great contributor to peace.

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KUWAIT

COMPETENCE IN SUSTAINABLE GROUNDWATER MANAGEMENT



Photo: D. Calma/IAEA



THE SITUATION

As an arid country, the scarcity of natural fresh water is a major developmental challenge for Kuwait. Inadequate rainfall compounded with high evapotranspiration rates drastically limits the availability of renewable water.

At the same time, increasing demand of water for human consumption, agricultural use and industrial development has put severe stress on available freshwater resources, both in terms of quantity and quality.

Kuwait relies heavily on seawater desalination, an expensive process which requires close monitoring to mitigate the potential impacts on the marine environment.

Taken in this context, groundwater remains Kuwait's only natural water resource.

However, the volume of available groundwater suitable for human consumption is limited and their continuous exploitation is associated with risks of groundwater mining and quality deterioration.

To meet the challenge, Kuwait has given top priority to the investigation and assessment of groundwater to support rational management of available resources. Over the past years, efforts increasingly focused on using isotope hydrology in combination with conventional methods to investigate groundwater resources for enhanced management.

The cooperation with the IAEA sustained over many years with the strong support and active

involvement of the national stakeholders has led to tangible achievements.

ACTIONS TAKEN

The sustainable development and management of groundwater resources requires an accurate assessment of its occurrence, availability and vulnerability to deterioration.

Isotope hydrology and its applications are effective tools in hydrological investigations. They are used to address practical problems and improve the accuracy and reliability of data for better assessment and management of groundwater.

Recognizing the benefits of using isotopic techniques, the Kuwait Institute for Scientific



Kuwait has integrated isotope hydrology applications in its water resources management programme (Photo: Water Research Center, KISR).

Research (KISR) adapted a strategic approach to develop the required infrastructure and technical expertise in isotope hydrology with support from the IAEA.

Guided by this strategic approach, KISR's Water Research Center (WRC) integrated isotope hydrology applications in its Water Resources Development and Management Programme during the last few decades.

A variety of isotopic techniques were established at WRC that were used to obtain critical information needed for the effective management of groundwater problems. Several technical cooperation projects on isotope hydrology were successfully implemented since 2003.

The contribution of the IAEA helped WRC to expand its knowledge base in water management and to develop a core of skilled research staff in isotope hydrology applications for groundwater assessment and management.

The experience accumulated through these projects has shown the importance of good practices to address the challenges.

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Technical cooperation projects in water resource management in Kuwait

Project	Title	Year
KUW7001	Using Isotope Investigations to Evaluate Groundwater Hydrology	2012-2015
KUW7004	Managing Groundwater Resources Using Stable and Radioactive Isotopes	2014-2019
KUW7006	Assessing Submarine Groundwater Discharge along the Coastal Area Using Radioisotopes	2016-2019
KUW8003	Isotope Hydrological Investigation of Fresh Groundwater Resources for the Development of an Optimum Utilization Strategy	2003-2009
KUW8004	Establishment of National Competence for Implementation of Inter-well Tracer Technology	2005-2009
KUW8005	Assessing the Hydrological and Hydrochemical Interaction between the Main Aquifers in Southern Kuwait Using Geochemical and Isotopic Methods	2009-2012

ACHIEVEMENTS

With the IAEA's continued support, WRC is now capable of carrying out studies on a range of groundwater issues and at providing services for large multi-disciplinary water projects.

The WRC staff developed skills in hydrogeology, hydrochemistry, mathematical modelling, water chemical and isotopic analysis using state-of-the-art equipment, water well drilling, water sampling from wells and surface water bodies, aquifer tests and geographic information system (GIS) technology.

Groundwater investigation studies carried out with IAEA support include:

- * Estimation of submarine groundwater discharge along the Gulf of Kuwait;
- * Investigation on the impacts of surface and subsurface drainage characteristics on the quality of fresh groundwater lenses in the Al-Raudhatain field in northern Kuwait;
- * Assessment of the hydrological and hydrochemical interaction between the Kuwait Group and Dammam Formation aquifers in southern Kuwait. The isotope techniques provided crucial information which helped in assessing the origin, age and movement of groundwater;
- * Evaluation of the potential contamination sources of nitrate and sulphate in the groundwater fields of Kuwait through isotopic characterization. The levels of naturally occurring radioactive materials in the groundwater were also investigated and showed that the major source of sulphate and nitrate in the groundwater is natural rather than as a result of human activity.

These studies generated numerous useful environmental isotopic data on Kuwait groundwater and resulted in several important outcomes that helped Kuwait tailor effective water management strategies.

LAO PEOPLE'S DEMOCRATIC REPUBLIC

RAPID DIAGNOSIS OF TRANSBOUNDARY ANIMAL DISEASES



not yet been reported in the country and there is a significant risk of their introduction from neighbouring countries.

Early and accurate detection plays a critical role in disease prevention and control. But conventional diagnostic techniques are not sensitive nor fast enough to provide timely and reliable test results. So Lao People's Democratic Republic requested IAEA assistance to establish local capability to use nuclear and molecular techniques for confirmatory diagnosis of TADs, and to help in establishing an early disease warning system in the country.

ACTIONS TAKEN

TC projects LAO5003 and LAO5004 were designed to support the National Animal Health Laboratory (NAHL) to improve its capability in the early and rapid diagnosis and control of the

THE SITUATION

Lao People's Democratic Republic is a relatively new IAEA Member State and only had its first TC programme in the 2014–2015 cycle. Its first Country Programme Framework covered the period from 2014–2018 and identified key national development priorities. This included areas where nuclear science and technology applications can offer a comparative advantage. Animal health and livestock production is one such area.

Livestock plays a significant role in the socioeconomic development of Lao People's Democratic Republic. It provides farmers with a source of income, draught power and organic fertilizer for crops. Furthermore, with rapidly

growing urbanization and increasing population growth, the livestock industry also has to meet the ever-growing demand for animal protein.

Lao People's Democratic Republic considers livestock production as an important part of the country's Food Security and Commodity Production Programme and continues to assist the private sector to strengthen its commercial-scale production. However, there remains a major constraint for livestock production to meet domestic and export demand — the occurrence of disease outbreaks in livestock population that are reported year after year.

Transboundary animal diseases (TADs), in particular, continue to threaten animal health and sustainable livestock production. While some types of TADs are endemic, others have



Biosafety Cabinet Class II installed at the NAHL Bacteriology Section, provided under TC Project LAO5003 (Photo: NAHL).



Handover of equipment provided under TC project LAO5003 to the National Animal Health Laboratory during an IAEA mission in August 2017 (Photo: NAHL).

various transboundary animal diseases in Lao People's Democratic Republic using nuclear and molecular techniques. The main project activities were implemented in 2016-2019 and included a procurement component, training and expert support.

The training of six NAHL management and professional staff took place in Germany, Thailand, Viet Nam and at IAEA Seibersdorf Laboratories in Austria on the following:

- * Theoretical and practical programmes in molecular diagnostic technologies for the early and rapid diagnoses and control of TADs and zoonotic diseases;
- * Early detection and differentiation of animal and zoonotic diseases;
- * Nuclear molecular detection polymerase chain reaction (PCR) and PCR sequencing, 2nd generation sequencing and the bioinformatics analyses of data;
- * Implementation of a Laboratory Information Management System with specific focus on QA/QC; and
- * The management aspects and operational workflow of a biosecurity level 3 laboratory

with respect to the biosafety and biosecurity including animal testing facilities.

This was complemented through the participation of NAHL staff in thematic training courses offered under the regional TC programme for Member States in Asia and the Pacific, as well as additional training by IAEA staff and experts visiting the National Animal Health Laboratory.

The expert support from IAEA also included implementation of molecular diagnostic protocols for TAD identification, assessment and support of laboratory proficiencies and capabilities.

The IAEA complemented the government's investment in the construction of a new modern building for NAHL which will also house an advanced Biosafety Level 3 Laboratory. This joint endeavour is going to receive further input in the TC cycles of 2022-2023.

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Kongsaysy Phommaxay, National Liaison Officer/Director General, Dept. of Science, Ministry of Science and Technology;
Phonesavanh Lathdavong, National Liaison Assistant/Director, Radiation and Nuclear Safety Division, Dept. of Science, Ministry of Science and Technology

ACHIEVEMENTS

The NAHL diagnostic team is well trained, hardworking, motivated and committed to deliver and achieve their objectives. The serological and molecular diagnostic capacities are moderately developed and the NAHL is able to make first line immunological and molecular nuclear and nuclear related diagnoses. More than 15 000 samples are being processed on an annual basis by the laboratory.

With the current achievements and further plans of involvement under the IAEA TC Programme, there is a great potential for improving the disease diagnostic and control activities in Lao People's Democratic Republic.

There are about 3 million cattle and buffalo, 3.1 million pigs, over 545 000 sheep and goats and 31 million poultry in the country, with a number of diseases as critical threats. In the short term, major advances can be made in the early and rapid animal disease diagnostics with medium-term advances in the analytical testing of contaminated animal products (for example, veterinary drug residues, antibiotic residues and toxin traces) for human consumption.

NAHL is moving towards becoming a reference and confirmatory diagnostic and control laboratory that would only occasionally rely on regional reference centre backup.

This can be achieved through IAEA's continued support to Lao People's Democratic Republic in the animal health domain.

LEBANON

NUCLEAR ANALYTICAL TECHNIQUES IN FRAUD DETECTION



Photo: M. Roumie/LAEC

THE SITUATION

The Lebanese Atomic Energy Commission (LAEC) is the designated centre of excellence in the field of analysis using nuclear and related analytical techniques.

The LAEC's analytical laboratories perform analyses at the request of national research institutions, universities, ministries, the Central Bank of Lebanon and local industries. The analyses could be for various types of samples, for example, environmental samples, food, archaeological artifacts, solid drugs, plastics, paintings, biological materials, ink and dyes, papers and documents, banknotes and coins. At the same time, the LAEC also contributes

to the development of local industries and research centres.

There was an urgent demand for the LAEC to develop analytical techniques with high precision and accuracy, as this level of precision was required to detect counterfeit materials and counterfeiting techniques. This, in turn, would make it easier to trace counterfeiters and to determine at which level of security the counterfeiters had been able to breach.

Counterfeit pharmaceutical products, coins, banknotes, documents, ink, adhesion compounds and printed textiles were among the products that were of considered to be particularly of high interest.

ACTIONS TAKEN

Taking into account the need to establish a new laboratory within the LAEC that would be dedicated to fraud repression and forensic issues, the LAEC started educating and training staff in the use of nuclear techniques in such sensitive domains. Three PhD students and one engineer received their education within this objective and they now form the scientific and technical nucleus of the new laboratory at the LAEC.

Lebanon proposed three technical cooperation projects which were approved by IAEA Board of Governors. These were LEB2007 (Enhancing the Capabilities of the Lebanese Atomic

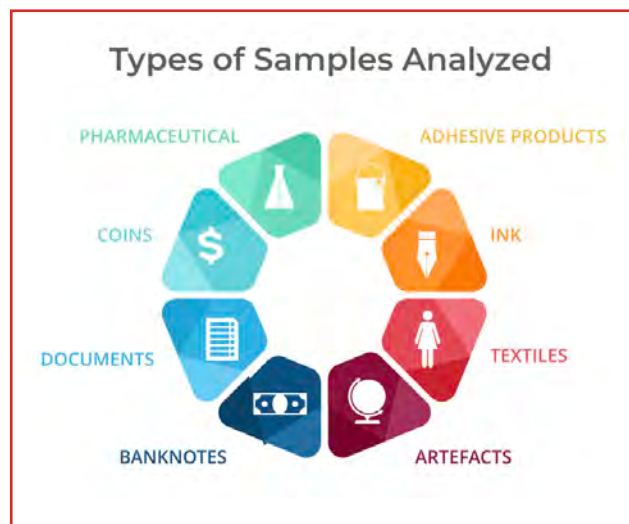
Energy Commission for Surface Chemical and Structural Analysis of Biological and Organic Materials); LEB1008 (Upgrading the Capabilities of the Lebanese Atomic Energy Commission for Surface Elemental, Chemical and Structural Analysis of Biological and Organic Materials); and LEB0007 (Strengthening Nuclear and Related Analytical Technique Capabilities in the Field of Forensic Sciences).

These projects would help the country acquire the necessary equipment and continue to increase staff skills through the human resource development components available from these projects.

Two of these projects enabled the LAEC to demonstrate the high potential and efficiency of nuclear and related techniques in the characterisation of high level counterfeited banknotes and counterfeited solid drugs.

The LAEC's overall objective was to upgrade and strengthen its capability to detect and characterise counterfeited material, and to be able to apply nuclear and related techniques in analysing a wide spectrum of counterfeit materials, especially when classical techniques have serious limitations.

Counterfeit pharmaceutical products are of particular high interest in fraud detection (Photo: R.Quevenco).



The projects were encapsulated in Lebanon's Country Programme Framework (CPF) with the IAEA for the period 2012–2017. The CPF emphasizes capacity building in nuclear and related analytical techniques, including human resource development, as a major pillar in Lebanon's national technical cooperation programme.

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ACHIEVEMENTS

One major achievement was the establishment of a new research and development structure at the LAEC, staffed with four skilled personnel (three PhD holders and one engineer).

The laboratory's programme and its extensive cooperation at the national and international levels have led to the preparation of 15 master theses. In addition, four PhD students have completed their research at the new structure which opened in 2012.

Two MOUs were signed; one with the General Directorate of Interior Security Forces (the Scientific Police) and another with the Central bank of Lebanon (Department of Cash Money).

The laboratory is used as part of regional cooperation between the Central Bank of Lebanon and some Arabic Central Banks. It is also used to train the criminal police and central bank staff to enhance the efficiency and effectiveness of the work needed to be done through this new laboratory.

The high level of scientific work done in the laboratory has given it an excellent scientific reputation in the country. The laboratory has widened its end user base for quality control and fraud repression to include the pharmaceutical and textile industries.

Hundreds of samples are now analysed in the laboratory each year, including banknotes, coins, drugs, pharmaceutical formulations, new materials, food and archaeological artifacts.

MALAYSIA

SUPPORTING INDUSTRIAL COMPETITIVENESS WITH NON-DESTRUCTIVE TESTING

THE SITUATION

Non-destructive testing (NDT) is the testing of engineering materials or components to detect and evaluate defects using methods and techniques which do not damage nor destroy the material under test. In general, NDT is used to improve the safety, quality and reliability of a product or system. Therefore, it has become compulsory for NDT to be implemented during construction, in-service maintenance and system repairs.

In Malaysia, NDT is applied for plant and structural integrity assurance in various types of engineering industry, especially in the sectors of oil and gas, power generation, aerospace, automotive, petrochemical, railway and manufacturing.

The development of the oil and gas industry in the early 80s had a positive impact on NDT, bringing significant changes to the field. Plants and factories which grew as spin-offs from the oil and gas industry made NDT an increasingly important testing technique.

Soon after, NDT end users began to realize that NDT inspectors must have a high level of skill and competency to ensure that test results are accurate and reliable. This led to the formation of industrial codes and standards to ensure that NDT can only be performed by qualified and certified personnel.

For example, a person performing NDT shall have gone through a minimum number of hours of formal training before he/she can take an examination for certification purpose.



Photo: Malaysian Nuclear Agency



Prior to the establishment of the local NDT industry, national oil and gas and power generation companies in Malaysia were highly dependent on expensive NDT services provided by foreign workforce and expertise.

This made the Government of Malaysia realize the importance and advantage of having its own national NDT certification scheme. The government then took rapid measures to establish a local workforce of trained and certified NDT practitioners in Malaysia.

ACTIONS TAKEN

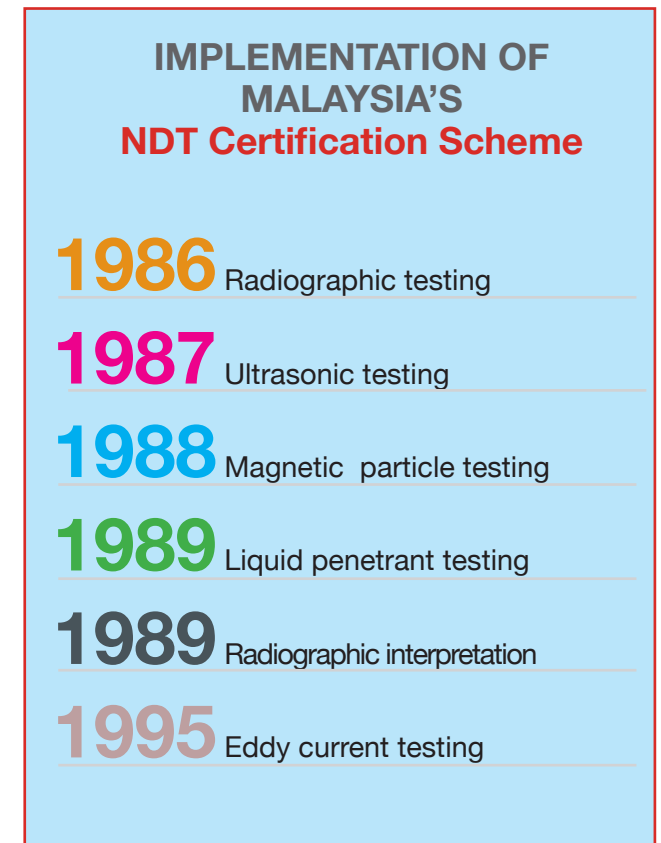
The Malaysian Nuclear Agency (Nuklear Malaysia) began to implement an IAEA technical cooperation project in the early 1980s. At that time, Nuklear Malaysia had identified the Department of Skills Development (DSD) under the Ministry of Human Resources as the National Certification Body (NCB) for NDT.

A committee was then established to develop the Industrial Radiographic Certification Scheme in January 1986. This

Expert missions, fellowships and scientific visits implemented under national IAEA technical cooperation projects

Project Code and Name	Expert Missions Received	Fellowships Attended	Scientific Visits Attended
MAL8006: Non-Destructive Testing Certification (1986–1995)	7	2	2
MAL8017: Advanced Non-destructive Testing of Structural Integrity in Components related to Oil and Gas Industries (2003–2009)	8	9	3
MAL8021: Establishment of Digital Radiography Methods and Procedures for Small and Medium-Sized Enterprises (2007–2012)	3	1	4
MAL1011: Developing Efficient Non-Destructive Testing (NDT) Data Management through Integrated NDT Modalities (2012–2013)	5	2	5
MAL1013: Enhancing the National Non-Destructive Testing Capabilities for the Nuclear Power Programme (2014–2015)	-	4	2
MAL1014: Establishing National Non-Destructive Testing Capacity for the Nuclear Sector (2016–2017)	1	8	8
MAL1016: Strengthening Capability in the Application of Nuclear and Related Technology in Industry (2018–2020)	-	-	3

Figure 1: Implementation of NDT Certification



committee was comprised of 15 members representing the private sector and various government agencies. Then in June 1986, a craftsmanship testing panel was established to take responsibility for administering the implementation of the NDT national examination.

Malaysia implemented its NDT certification scheme in stages, as shown in Figure 1. Some of the NDT certifications were needed urgently due to legal and safety factors. The NDT certification schemes were based on the ISO 9712 standard and the syllabus was developed following IAEA recommendations and guidelines.

Getting international recognition

The national NDT certification scheme is continuously developed and updated with the goal of making the scheme equal to that of other NDT certification schemes around the world.

In 2005, an effort was initiated to accredit the national-level NDT certification scheme in compliance with the ISO 17024 standard. This effort was made in collaboration with the IAEA. Its final objective was to ensure that NDT certificates issued by NCB are recognized not only nationally but also internationally.

The DSD, acting as the NCB for NDT in Malaysia, undertook various efforts to achieve this objective. In 2010, the documents, which described the quality system practiced by the NCB, were completed and then audited by the Department of Standards Malaysia, the national accreditation body. In 2012, the DSD was accredited as the Personnel Certification Body for NDT based on the ISO/IEC 17024:2003.

The IAEA helped to develop local expertise by providing experts and organizing fellowship trainings and scientific visits. With IAEA assistance, and in collaboration with the DSD, Standards and Industrial Research Institute

of Malaysia, and the Atomic Energy Licensing Board, Nuklear Malaysia conducted the first NDT training course in Radiographic Testing in 1986. Since the first national training course, Malaysia has taken steps to produce qualified and certified NDT personnel to serve local industries.

Worker at a car assembly plant in Malaysia. (Photo: A.Razak Latif/123RF.com)



ACHIEVEMENTS

The implementation of the national NDT certification scheme has produced skilled professionals in the field of NDT required for national development.

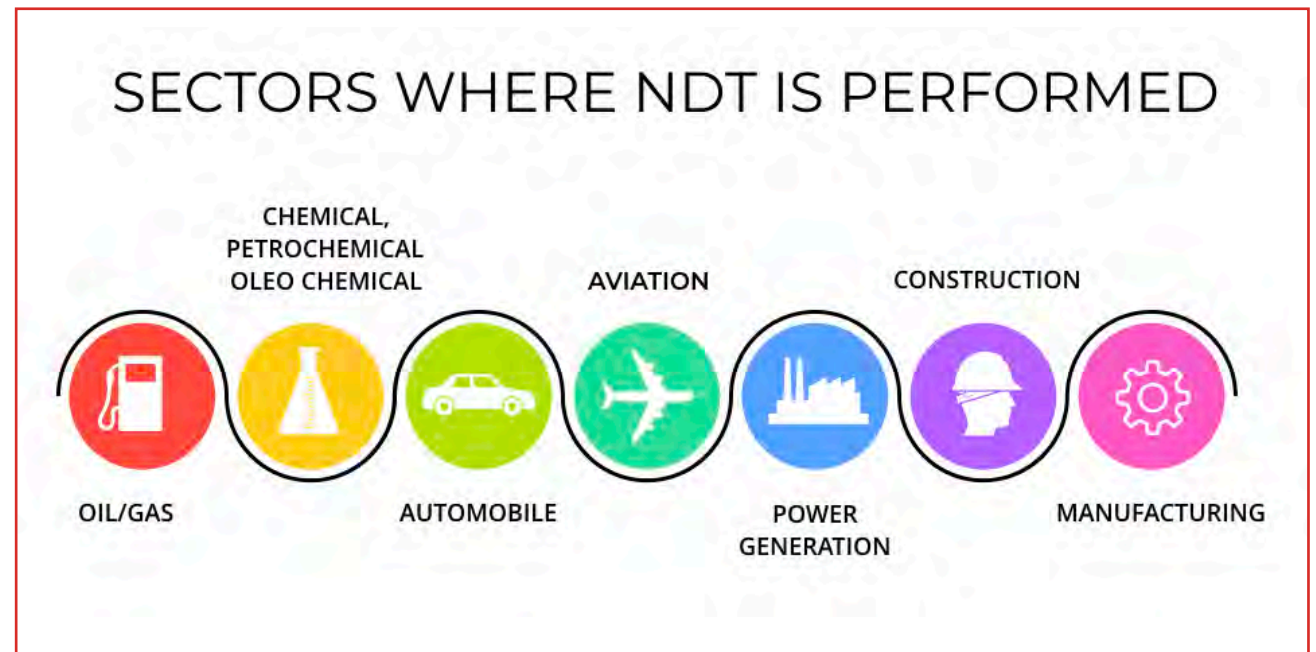
More than 9000 personnel have undergone training in various NDT methods and at various levels of competencies. From this number, over 4000 are certified NDT inspectors. They work with more than 90 local NDT companies providing testing services in various sectors.

The majority of certified NDT personnel in Malaysia are in the radiographic testing (RT) method. The RT method is often used in the oil and gas industries to inspect components, such as pressure vessels and valves, to detect flaws.

Milestones:

With the accreditation of the DSD as Personnel Certification Body for the scope of NDT based

Figure 3: Sectors where NDT is performed



on MS ISO 17024: 2003, Malaysia became the fourth country in Asia and the Pacific region where the NCB for NDT is accredited according to ISO 17024:2003. The three other countries are Australia, New Zealand and China.

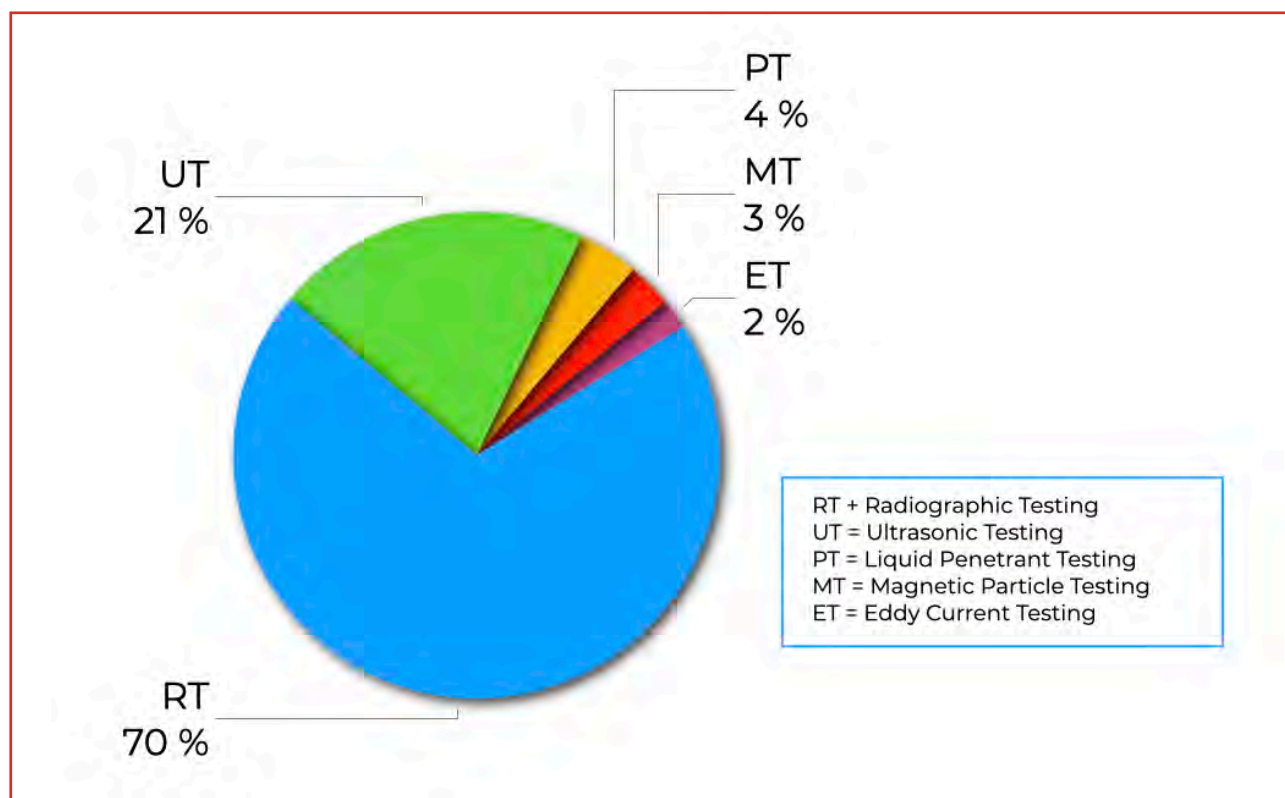
The establishment of an internationally recognized NDT training, qualification and certification scheme in Malaysia has contributed to the improved safety and optimized operation of industrial plants. Apart from providing NDT services using local workforce, NDT has also enhanced the employment prospects of graduates and non-graduates.

Companies in the oil and gas sector account for around 70% of all NDT inspection business in Malaysia. Power plants, shipyards and the aviation industry are other important clients benefiting from this technology. The cost of local inspections is about one fifth of the cost of hiring inspectors and using technology from overseas.

In 2015, the IAEA designated Nuklear Malaysia as the IAEA Collaborating Centre for NDT until 2019. This was a significant achievement in the area of NDT. It provides close and valuable cooperation between Malaysia and the IAEA in various regional activities, including research, development and training.

Malaysia's NDT certification system was also recognized by the International Committee for

Figure 2: Percentage of certified NDT personnel according to NDT methods





Companies in the oil and gas sector account for around 70% of all NDT inspection business in Malaysia (Photo: Nachai/123RF.com).



Malaysia's NDT training programme (Photo: Malaysian Nuclear Agency).

Non-Destructive Testing for the Multilateral Recognition Agreement. In 2018, the President of the Malaysian Society for Non-Destructive Testing (MSNT) was awarded the Prime Minister's Award for his contribution to the establishment and promotion of the national certification scheme for NDT.

The national certification scheme for NDT in Malaysia was developed, established and sustained due to the excellent collaboration and partnership between the DSD as the NCB, Nuklear Malaysia as the NDT training centre, the Atomic Energy Licensing Board as the regulatory body, the MSNT, and with strong support from the IAEA.

Malaysia's training system and national NDT certification scheme have become reference

centres for many countries. Sudan, for example, has adopted Malaysia's certification scheme.

Malaysia also receives prospective inspectors from Myanmar, Sri Lanka, Syrian Arab Republic and others for training and certification. From 1994 to 2018, Malaysia has trained 59 fellows and scientific visitors from other countries in the area of NDT.

The success of Malaysia's NDT training programme can serve as a model and inspiration for other countries wishing to develop their own national NDT certification programme.

Technical support provided by Nuklear Malaysia to the Regional Training Course on Digital Industrial Radiography and Industrial Computed Tomography (implemented under

RCA project RAS1020) enabled the IAEA to deliver ISO 9712:2012 Level-2 training and to conduct examinations on digital radiography in accordance with the syllabus of the Australian Institute for Non-Destructive Testing.

This was a breakthrough result achieved for the first time in the framework of an RCA project, in which a regional training course was done with theoretical and practical examinations, leading to an internationally recognized certification in accordance with ISO 9712:2012 standards.

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MARSHALL ISLANDS FOR THE GOOD OF MANKIND

| THE SITUATION

What is nuclear energy and radiation? More importantly, how are these terms defined in the native Marshallese language?

These questions still haunt the local population seventy years after the nuclear tests in Bikini and Enewetak Atolls, which had a profound impact on the natural landscape and the indigenous population.

Certain local governments in partnership with US Government agencies have implemented a number of strategic initiatives over the past decade to improve radiological surveillance measures in the atolls.

At the time of the Fukushima accident in 2011, national capability to undertake monitoring for public reassurance purposes and to support the important Marshallese fishing industry was lacking. The Marshall Islands is also cognizant of the fact that nuclear

energy production in Asia and the Pacific region is expanding and, the Marshall Islands, as a nation, needs to have some capacity to respond to nuclear events.

The Marshall Islands also needs to be able to make more informed decisions on issues related to radiation exposure, remediation and resettlement of islands and atolls, and general radiological safety and health.

| ACTIONS TAKEN

In late 2015, the IAEA assisted with the development of a technical cooperation project to build independent national capacity to monitor and analyse artificial radionuclides in the marine, terrestrial and coastal environments of the Marshall Islands.

The two national agencies responsible for this project are the Marshall Islands Environmental Protection Agency and the Marshall Islands Marine Resources Authority, whose mandate covers both the terrestrial and marine environments.

The project Developing National Radioactivity Monitoring Capacity (MHL7003) will provide baseline data on artificial radionuclides in terrestrial and marine environment of the Marshall Islands against which any future inputs can be compared.

The successful implementation of this project can improve public awareness and understanding of the radiological conditions in the Marshall Islands. It can also provide the basis for a robust, continuing monitoring and assessment programme in the Marshall Islands

beyond the lifetime of the project. The ability to conduct independent national studies in radiological protection and measurement will also help in developing stronger partnerships and collaborations with other Member States.

The measurement of gamma-emitting radionuclides can only be made with the use of nuclear techniques, So the IAEA is supporting the transfer of technology in the Marshall Islands along with supplemental equipment and laboratory supplies needed for project implementation.





Photo: R. Quevenco

ACHIEVEMENTS

From 2016–2019, the knowledge and skills of national project counterparts in the basic aspects of radiation have substantially increased from zero/minimal to a good understanding of the components, radiological sampling strategies and use of gamma spectrometry equipment, to name a few. Two more years remain in this project and it is expected that knowledge and skills will be enhanced by then.

In 2017, the Marshall Islands National Nuclear Commission was established to develop a detailed strategy and plan of action for pursuing justice, in relation to the nuclear weapons testing program and its effects in the Marshall Islands. Project counterparts have met with this commission to build and foster a relationship that will not only benefit the national and local levels, but also local communities using the holistic approach. This Commission has an Education and Awareness Officer who can assist with project activities which raise awareness on basic aspects of radiation. Also, at the national level, the project counterparts can/will assist the Commission on research or radiological expeditions.

With more capacity building and as knowledge and skills are enhanced, the Marshall Islands will have an independent national capacity to monitor and analyse artificial radionuclides in the marine, terrestrial and coastal environments which will then improve informed decision making of government authorities regarding radiation contamination and the management of natural resources.

The main beneficiary of this technical cooperation project is the indigenous population of the Marshall Islands.

The IAEA will also support manpower development and provide expert assistance in order to enhance the knowledge and skills of project counterparts in the Marshall Islands.

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Photo: A.Mijatovic/123RF.com



MONGOLIA

SUCCESS IN THE HEALTH CARE SECTOR

| THE SITUATION

Cervical cancer is the second leading cancer for women in Mongolia. Most of these cases are diagnosed in late stages, when treatment options including radiotherapy and intracavitary brachytherapy, can play a major role in dealing with this disease.

Over 200 cervical cancer patients in Mongolia receive brachytherapy each year. The most commonly used brachytherapy method is an X-ray-based two-dimensional (2D) brachytherapy, using standard reference points defined by the International Commission on Radiation Units and Measurements.

Recently, 3D images acquired by computed tomography (CT) and magnetic resonance imaging (MRI) have increasingly been used for treatment planning in brachytherapy. These imaging modalities provide more accurate information than X-rays on the spatial relationship of the radioactive sources, the tumour, and organs at risk.

The treatment planning using 3D images for dose distributions and dose-volumes allows for better quality assessment and evaluation of tumours and organs that are at risk. Clinical studies also show that this approach can optimize treatment results by improving local tumour control and by decreasing the side effects and complications.

Mongolia believes that the introduction of 3D image-guided brachytherapy will improve the quality of the country's brachytherapy treatment and greatly benefit the cancer patients receiving such treatment.

Mongolia likewise puts significant emphasis on upgrading its human resource capability. Radiation oncologists typically complete a two-year oncology residency training at the National Cancer Centre (NCC) prior to a 6-month course. Medical physicist, maintenance engineer and radiation therapists need to complete a 3-6 month course based on IAEA guidelines.

As Mongolia adopts more advanced technologies in cancer therapy, it will require

longer periods of compulsory training for its specialized professionals in developed countries. Mongolia further plans to invite experts from these countries to work with its medical professionals to help address and solve problems in the workplace.

An IAEA technical cooperation project has helped Mongolia address issues related to the purchase of CT-MRI compatible applicators, software; replacement of old cobalt-60 sources; and human resource development.

ACTIONS TAKEN

Mongolia has improved brachytherapy quality assurance and quality control after tackling these three issues:

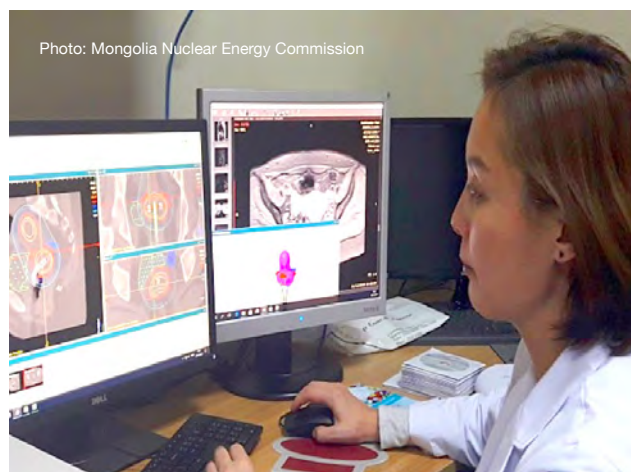
- * Introduction of advanced brachytherapy equipment and technologies,
- * Advancing personnel knowledge and skills in these technologies and
- * Developing treatment standards.

Introducing advanced brachytherapy equipment and technologies

The brachytherapy accuracy has been improved by the purchase of CT-MRI compatible applicators and by upgrading the treatment planning software. The applicators were received on September 2017 and August 2018. The treatment planning software was updated on December 2017 and was connected to the CT simulator, with subsequent staff training.

It is predicted that improved treatment will reduce side effects and complications, consequently improving patients' life quality and expectancy. A new cobalt-60 source was purchased and will be put into use with IAEA support.

Quality assurance and quality control in brachytherapy have improved, and compliance



3D image-guided brachytherapy has improved the quality of cancer treatment in Mongolia.

with international standards is assured with the help of dosimetry devices and expert missions.

Improving personnel knowledge and skills in advanced technologies

To further improve its human resource capability, Mongolia has applied for a fellowship

programme, a scientific visit, and requested for an expert mission within the project framework. In line with this, a national workshop and an expert mission were held in Mongolia in November 2019.

Developing treatment protocols

With the introduction of new technologies, treatment protocols are likewise being developed. Each protocol was developed at the same time as the technique's application process.

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ACHIEVEMENTS

Image-guided brachytherapy, Mongolia's proposed next step in advanced technology, was initiated in 2014. A technical cooperation project proposal entitled To Improve Brachytherapy Quality Assurance Through Introducing 3D Image-Guided Brachytherapy Service in Mongolia, was submitted to the IAEA and approved with a €201 660 budget for 2016–2017.

With IAEA approval, the CT based image guided 3D brachytherapy for locally advanced cervical cancer was introduced in Mongolia in the last quarter of 2018.

To date, 273 cervical cancer patients have benefited from the Three-Dimensional Insulated Gate Bipolar Transistor (3D IGBT), and a total of 941 procedures were done. Four radiation oncologists and two medical physicists were trained through IAEA regional training courses, and a national seminar was held to train other technicians and nurses.

There is a great opportunity to dramatically improve the radiation therapy effectiveness for locally advanced cervical cancer. However, due to lack of brachytherapy equipment and workload distribution, 20% of Mongolia's cervical cancer patients cannot be treated by 3D IGBT.

Endpoint results such as improvement of tumour control, patient survival and reduction of toxicities have yet to be established.

MYANMAR

BUILDING CAPACITY IN VARIOUS NUCLEAR TECHNOLOGIES



Photo: N. Witropart / 123RF.com



long droughts, and erratic rainfall patterns and intensity.

Radiotracer and NDE techniques

Myanmar's three main coastal zones face the Indian Ocean, Bay of Bengal and Andaman Sea. There are 11 ports and harbours located along this wide coastal area which play a major role in Myanmar's economic and social well-being.

Myanmar spends a large amount of money on studies concerning sediment transport and dredging activities. The studies help in selecting the right alignments for new navigation channels and in discovering ideal sites for disposing of dredged sediments. The application of nuclear-based technologies will give Myanmar a more effective technology for sediment management of its ports and harbours.

Watershed management

Although other studies have analyzed the sedimentation and water quality in Inle Lake and its surrounding regions, no study using nuclear technology has been done yet. From 2015 to 2018, Myanmar, with the support of IAEA, launched two technical cooperation

THE SITUATION

AEA technical cooperation activities in Myanmar focus on three main areas: mutation breeding, radiotracer and non-destructive evaluation (NDE) techniques and watershed management.

Mutation breeding

Rice is a staple food in Myanmar and economically very important. To feed Myanmar's current population of 55 million and meet its export needs, farmers have to cultivate nearly 7 million acres of rice fields.

However, rice production in Myanmar is gradually being reduced by yield loss, urbanization, water shortage, pests and disease, salinity and the impacts of climate change. Myanmar is besieged with floods,

Technical cooperation projects in Myanmar on using nuclear isotopes techniques to measure water quality and sedimentation in Inle Lake.

Project	Title	Purpose
MYA5025	Monitoring and Assessing Watershed Management Practices on Soil Erosion and Sedimentation Rates of the Inle Lake	To gather soil samples and use the environmental fallout radionuclides (FRNs) technique to assess soil erosion and sedimentation rates.
MYA5027	Monitoring and Assessing Watershed Management Practices on Water Quality and Sedimentation Rates of the Inle Lake	Training on water stable isotopic techniques and its application in assessing water quality prior to sampling.

projects on using nuclear isotope based monitoring and assessment techniques on water quality and sedimentation (see table).

ACTIONS TAKEN

Mutation breeding

Support from the IAEA and the Myanmar government has contributed to the success in applying nuclear techniques in food and agriculture. It also enabled Myanmar to achieve sustainable agricultural production both in the areas of mutation breeding and in efficient soil and water management.

Demonstrations on efficient soil and water management practices are continually being carried out to help local farmers increase rice production and obtain maximum yield from the mutant variety. They focus on rice cultivation techniques, good fertilization practice, and efficient water management for sustainable rice production. Farmers have benefited extensively from the techniques transferred through these demonstrations.

Radiotracer and NDE techniques

Radiotracer and sealed source techniques were introduced in Myanmar in 2012 with the support of the IAEA. These techniques provide information on the density and amount of the sediments deposited in a channel of navigation or harbour basin. They are also able to disclose the concentration of sediments circulating in suspension. The suitability of the selected location for dredged materials can also be confirmed using the techniques.

Two national projects carried out by the Department of Atomic Energy (DAE) have enhanced Myanmar's capacity in radiotracer and sealed source techniques, as well as its capacities in conventional and advanced NDE techniques in local industries like oil and gas.

To achieve professional skills development and career advancement, a human resource development programme in industrial applications of radioisotope technologies was carried out through a national technical cooperation project in 2012.

Watershed management

In the first phase of the project, the Department of Forest Research Institute gathered quantitative information on soil erosion and sedimentation rate in and around Inle Lake over a range of different timescales using fallout radionuclides measurements.

In the second phase, water samples were collected, first in February 2018 and then in December 2018. The initial samples were sent to USA and Australia for water stable isotopic analysis. The second samples are presently



Rice farmers in Myanmar benefit from improved agricultural techniques (Photo: Szepei/123RF.com).

being processed. Results from the first sampling has been communicated to the IAEA through Australia's technical experts.

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ACHIEVEMENTS

Mutation breeding. With IAEA's support, Myanmar produced a mutant rice variety (Sin Shwese) that is high yielding, of good quality and with a shorter maturation period. With this variety, farmers are able to grow winter pulse crops and grow rice twice a year. The fields are productive the whole year round, enhancing farming activity and cropping intensity, and increasing the income of farmers and rural workers, including women. The new rice variety has also been beneficial to farmers facing a shortage of irrigation water.

Radiotracer and NDE techniques. To share knowledge and information, a seminar on Radiotracer and Non-Destructive Evaluation Techniques in Industry was held in Yangon, Myanmar. The seminar provided a chance for hands-on experience with different radiotracer and non-destructive evaluation equipment and techniques.

Watershed management. Myanmar was able to obtain knowledge, skills and software applications to assess soil erosion, sedimentation and water quality using stable isotopic techniques.

NEPAL

STRENGTHENING NUCLEAR EDUCATION AND TRAINING

THE SITUATION

Nepal is working to enhance overall national welfare through the peaceful use of nuclear technology by utilizing it for the economic and social prosperity of the country. But to properly use nuclear technology requires adequate expertise and skills.

Tribhuvan University is the pioneering institution for higher education in Nepal, and is responsible for developing the expertise and skills required for the proper use of nuclear technology. However, university facilities are more than 50 years old and are no longer in a condition to even provide training to the students. So, in most cases, the university only offers theoretical classes and the most basic experiments.

Almost all the nuclear experts in Nepal received their education and/or training at Tribhuvan University; so it was important that future graduates receive hands-on experience at a well-equipped centre before they can work in their related fields.

Nepal, therefore, cooperated with the IAEA on a TC project, 'Developing Capacity for Nuclear Physics and Nuclear Chemistry

The Tribhuvan University in Nepal.



Photo: Tribhuvan University



Photo: M.Kurylchyk/IAEA

Teaching Programmes at Tribhuvan University' (NEP0002). Its main objective was to provide a learning opportunity so specialists in various areas of nuclear physics and chemistry, with adequate expertise and skills, are produced within the country.

ACTIONS TAKEN

Long before the project was formally launched, various rounds of meetings and workshops were organized to prepare a roadmap for the implementation of the project. A project management team was also set up and met regularly.

A preparatory project was launched by the Ministry of Education Science and Technology (MoEST) on Status of Radioisotopes in Nepal — A Survey for the Preparation of Inventory (2010), and it played an important role in guiding the activities.

The project identified what type of human resources and training were needed to support nuclear activities being carried out in the country, and aimed to develop expertise and skills in the use of nuclear techniques. It also outlined in detail the changes to be made in the experimental facilities and prepared the list of new equipments needed.

Some of the training activities conducted in support of TC project NEP0002

Activity	Venue	Date
Interaction Programme on Nuclear Technology	Kathmandu	10 April 2016
Orphan Source Search Training	Kathmandu	18–22 July 2016
Interaction Programme on Nuclear Technology	Kathmandu	5 July 2016
Training on PGIS-2 for Radiological Mapping	Kirtipur, Nepal	27–28 July 2016
Training of Laboratory Assistants	Kirtipur, Nepal	28 Aug–2 Sept 2016
Orphan Source Investigation in Kathmandu Metropolitan Area	Kathmandu	21–25 Nov 2016
Workshop on Emergency Preparedness and Response Related to Nuclear Radiation in Nepal	Kathmandu	7–9 June 2017

Thus prepared, Nepal presented the plan to the IAEA for discussion and to narrow down the options.

Scientific visits by two of Nepal's project team members to the IAEA's Nuclear Science and Instrumentation Laboratory in Seibersdorf, Austria were helpful in gaining familiarity with different types of equipment involved.

The next steps were to procure the equipment, prepare the local infrastructure, and train the people involved. At this stage, IAEA support was crucial in planning and deciding the activities. Thus, basic facilities like laboratory space, power supply, human resources, and others were well prepared before the first lot of equipment arrived.



Once the Nuclear Research Laboratory was functional, various training activities were held to handle the new set of equipment, and experiments were conducted, as and when required. The training activities covered diverse topics, for example, basic handling of equipment, solving real situations, and many others (see table).

In addition, the laboratory worked together with the MoEST on outreach activities targeted towards various audiences, from the general public, school teachers, health technicians, bureaucrats, to members of parliament.

ACHIEVEMENTS

The laboratory facilities for undergraduate and graduate students have been significantly improved with the introduction of new laboratory equipment and other supporting facilities. In addition, the Nuclear Research Laboratory enables students to work on their MSc projects. In fact, a student worked there on a PhD in Radiological Mapping by In-Situ Gamma Ray Spectrometry.

Nepal now has the capacity to detect any form and level of ionizing radiation. The laboratory facilities are also being used by the MoEST in regulatory and monitoring activities.

Today, 120 graduate students are being trained annually for basic experiments like calculation and comparison of activities, half-life determination, absorption and back scattering by various media, estimation of natural background, and in-situ gamma ray spectrometry, among others.

About 10 students are trained every semester, in the form of their project activities and also whenever required for specific purposes.

After implementing this project, the following are some of the important outcomes:

- * A Nuclear Research Laboratory with sufficient detectors, computer facilities, analysis software, standard sources, and reference materials is now operational;
- * New experiments at the graduate-student level have been introduced. Annually, about 10 projects related to nuclear activities are conducted by MSc students; one PhD programme is registered;
- * MoEST received support for training and awareness activities, licensing and monitoring of radiation facilities, and drafting and implementation of nuclear law;
- * Technical expertise was provided in the establishment of a Nuclear Research Centre, operating under the MoEST; and
- * A Radiological Map which helps in successfully locating orphan sources and securing them was prepared.

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THE SITUATION

Malaria was a major health problem in the Sultanate of Oman in 1990 with 30 000 diagnosed cases. Over the years, the situation has markedly improved. For example, in 2012 there were just over 2000 malaria-positive samples reported.

However, the Ministry of Health's annual report (2017) shows a persistent and constant number of imported malaria cases that exist as asymptomatic infection prior to the onset of the disease's symptoms.

Malaria parasites among asymptomatic carriers often occur at low density, close to or below the levels of threshold of microscopy detection (between 50 and 200 parasites per μL) (McMorrow et al., 2011). These cases escape microscopy diagnosis, the method of choice in the Central Health Laboratory of the Ministry of Health.

As a result, the number of imported malaria cases in Oman has been on the rise (see figure). Local malaria outbreaks occur regularly, presumably seeded from imported cases not identified in a timely fashion and treated to prevent transmission to the indigenous *Anopheles* population.

For its control programme, the country reports a high degree of success using larvaecides and anti-malaria drugs. However, the reported regular malaria outbreaks has denied Oman a malaria-free status.

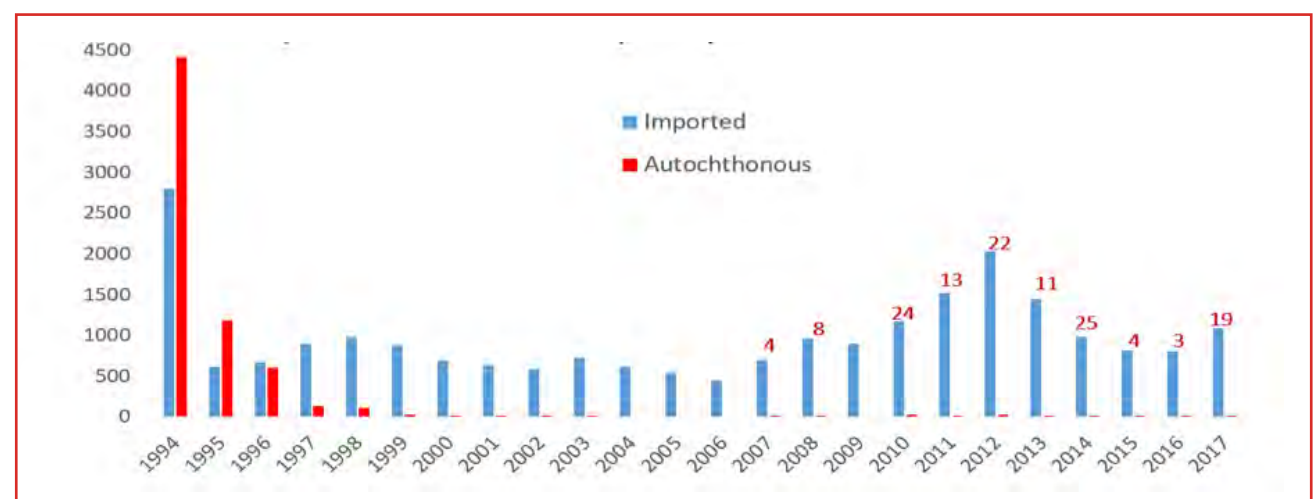
ACTIONS TAKEN

The current screening procedure, microscopy, is labour intensive. It misses asymptomatic malaria cases with a low parasitaemia that are below the detection threshold for microscopy, 50 to 200 parasites per μL of blood by an average microscopist (Nwakanma DC et al. 2009).

Molecular methods such as the polymerase chain reaction (PCR) can detect as low as a 1 to 2 parasites per μL of blood (Nwakanma et al., 2009). This is approximately 100-fold lower than the threshold of detection by microscopy.

To be effective, there is a need for sensitive and cost-effective malaria surveillance among asymptomatic migrants from malaria endemic

Imported and autochthonous (locally acquired) malaria cases detected by microscopy in the Sultanate of Oman, 1990-2017



countries. The lack of this type of surveillance represent a great hindrance to the prospect of malaria elimination in Oman.

Support from the IAEA

The IAEA supported the project OMA6006 during 2016–2017 to develop diagnostic capabilities in the use of molecular and radionuclide techniques for the detection of malaria cases among asymptomatic migrants from malaria endemic countries.

These techniques identify drug resistant parasites that escape the effects of some anti-malarial drugs. Previous studies have demonstrated that the addition of radiolabeled nucleotides to PCR based assay enhances the specificity and sensitivity of detection of drug resistant parasites (Ranford-Cartwright et al., 2002).

While the conventional assessment method of drug resistant malaria parasites is slow,

logistically demanding and requires lengthy patient follow-up, the molecular techniques that apply radio-labelled methods is faster, has a high throughput and can analyze multiple samples at once.

The radio-labelled probes have also demonstrated high sensitivity, detecting as little as 0.1 pg of target DNA. The method further shows robust reproducibility, making the dot blot/probe hybridization technique an adequate tool for large scale epidemiological surveys of genes associated with drug resistance.

The molecular diagnosis techniques for malaria parasites, *Plasmodium falciparum* and *P. vivax*, were established in the Biochemistry Department of the College of Medicine and Health Sciences in Sultan Qaboos University, Oman.

An IAEA expert assisted in the development of species-specific oligonucleotide probes

quantitative PCR (qPCR) assay for the detection of the common human malaria parasites in Oman (*P. falciparum*, *P. vivax*).

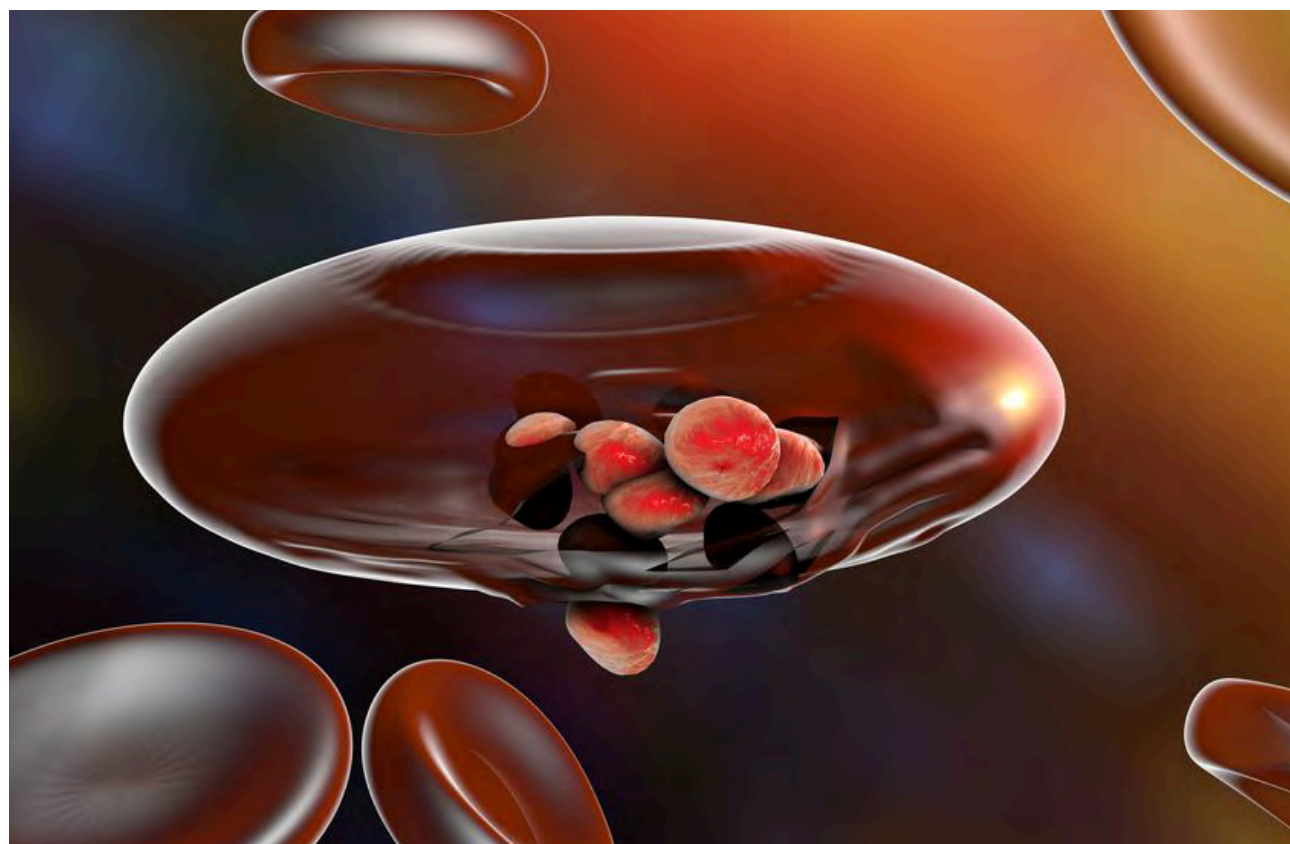
Fellowships and training

At the same time, an IAEA fellowship training was organized for two staff of the Biochemistry Department of the College of Medicine and Health Sciences. Additionally, the following major new equipment were provided by the IAEA and subsequently installed:

- * A qPCR machine,
- * Hybridization oven,
- * Hybridization tubes and
- * A cold centrifuge.

The established molecular assays were then used to screen 324 samples collected from healthy individuals arriving at Muscat International Airport from malaria endemic sites.

Left to right: Malaria parasites released from infected blood red cells and a mosquito feeding on a human finger, (Photo: Kateryna Kon/123RF.com).



Sixteen individuals were found to harbour *P. falciparum* and six other had the *P. vivax* malaria parasite, respectively. All of the selected individuals had tested negative by conventional diagnostic methods, microscopy and/or rapid diagnostic tests.

The Biochemistry Department of the College of Medicine and Health Sciences trained three staff of the Central Health Laboratory of the Ministry of Health on methods for molecular diagnosis of malaria parasites and transferred the protocols that it had developed.

Through an IAEA fellowship, a staff member from the Central Health Laboratory of the Ministry of Health was trained on the use of qPCR for the detection of malaria parasites, *Plasmodium falciparum* and *P. vivax*, at the Medical Research Council Unit in the Gambia, which is affiliated to the London School of Hygiene and Tropical Medicine in the UK.

Close collaboration

This close collaboration has encouraged the Ministry of Health to establish facilities for



Technical staff performing PCR for detection of genes associated with drug resistance in *P. vivax* in the laboratories of the Biochemistry Department, College of Medicine and Health Sciences, Sultan Qaboos University (Photo: Peaceful Nuclear Technology Office, Oman).

molecular detection of malaria parasites at the Central Health Laboratory for its Malaria Eradication Programme.

Molecular assays are also used to screen arriving passengers for malaria at the Muscat International airport in Oman (Photo: Oman Airports).



Through IAEA project OMA/6/006, the radionuclide-based molecular method and amplicon sequencing were established for the detection of imported drug resistant malaria in the Biochemistry Department, College of Medicine and Health Sciences, Sultan Qaboos University.

The new technology for monitoring of drug resistance mutations in the malaria parasite *Plasmodium falciparum*, using next generation sequencing (Ion Torrent) was further established with the assistance of an IAEA expert.

Training of a staff of the Sultan Qaboos University and the Central Health Laboratory of the Ministry of Health in this new technology was also implemented.

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Conway DJ. (2009) Quantitative detection of Plasmodium falciparum DNA in saliva, blood, and urine. J Infect Dis. 2009 Jun 1; 199(11): 1567-74.”

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Sultan Qaboos University, located in Al Khoudh, is the only public university in the Sultanate of Oman.

ACHIEVEMENTS

- * In terms of technology, species-specific oligonucleotide probes for detection of human malaria parasites (*P. falciparum*, *P. vivax*, *P. malariae* and *P. ovale*) were developed and protocols for radionuclide-based molecular methods to detect mutations in dhfr and dhps genes that cause resistance of the malaria parasites to sulfadoxine/pyrimethamine (Fansidar) were established;
- * An array of molecular methods to detect and quantify *P. falciparum* and *P. vivax* infection and determine their prospective response to known antimalarial drugs were also established;
- * In addition, molecular assays to identify the transmission stages of *P. falciparum* and *P. vivax* as well as their genetic background have been developed. These methods allow analysis of the origin of malaria parasites that cause local transmission (outbreaks) and allow the development of an effective approach to contain outbreaks;
- * Three staff each from the Biochemistry Department and the Central Public Health Laboratories, have been trained in molecular techniques for diagnosis and genetic characterization of the common malaria parasites, *P. falciparum* and *P. vivax*. They are currently holding positions in their respective scientific and medical institutions;
- * The close collaboration between the Biochemistry Department of the College of Medicine and Health Sciences of Sultan Qaboos University and the Central Health Laboratory of the Ministry of Health has resulted in fully operational facilities for molecular detection of malaria parasites at the Central Health Laboratories of the Ministry of Health;
- * In order to curb local outbreaks caused by imported malaria larvae, the Ministry of Health has considered shifting to a new policy for screening all migrants coming from malaria endemic countries, using molecular diagnostic methods. This will strengthen the “detect and treat” strategy of the country’s Malaria Eradication Program, prevent re-introduction of local transmission and eventually lead to a malaria-free Oman.

PACIFIC ISLAND MEMBER STATES

TAKING A SUB-REGIONAL APPROACH TO SHARED CHALLENGES

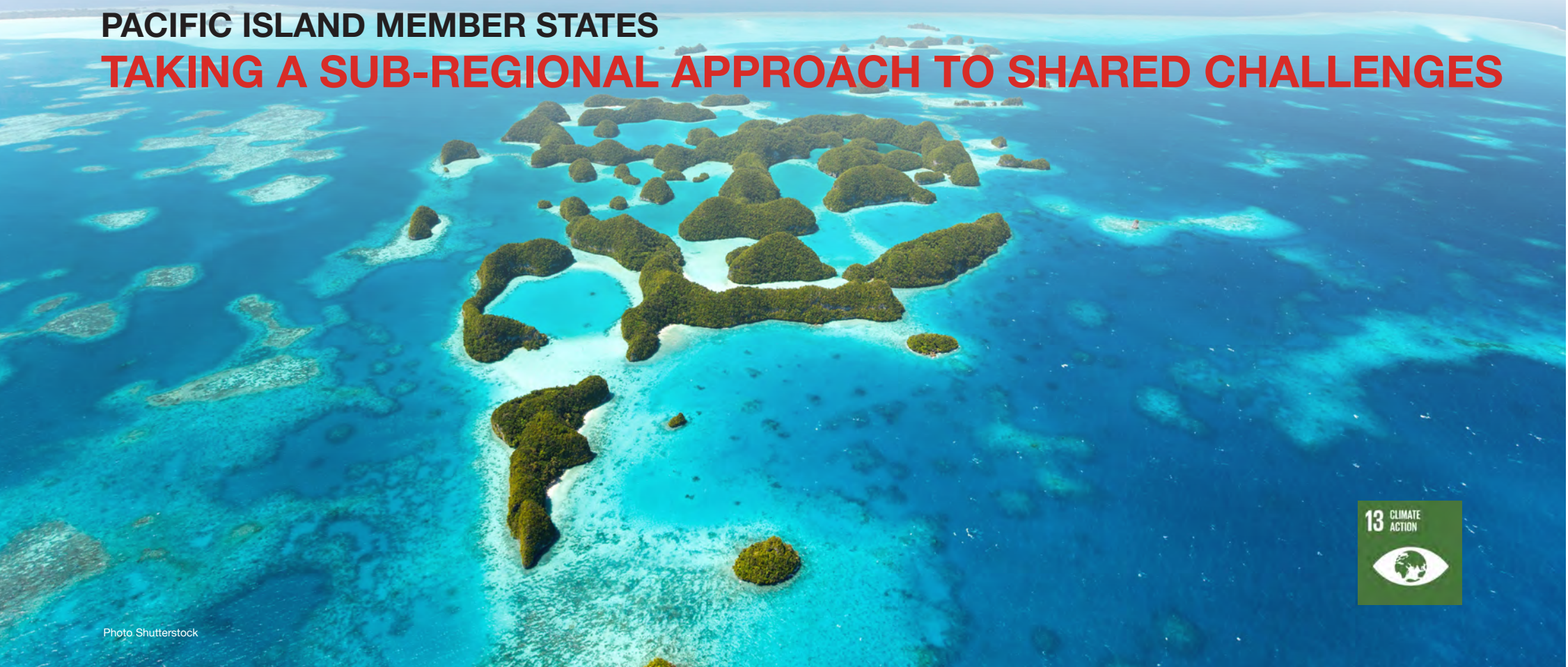


Photo Shutterstock



THE SITUATION

The Pacific Island countries of Fiji, Marshall Islands, Palau, Papua New Guinea and Vanuatu all joined the IAEA as Member States between 2012 and 2016. These small island countries face many shared challenges that are unique to their sub-region (see figure). Nuclear technology can help in all of these areas.

Nuclear-derived techniques, for example, can be applied to measure and monitor the impacts of ocean acidification and help identify the sources of pollution in the sea. This is crucial information for a group of people who rely heavily on the sea for their food and income.

Nuclear technology can also help countries struggling with limited land space to better manage their water resources through smart



agriculture and to develop new crops that are resistant to salty soil.

In order to address shared issues across these small island countries, the IAEA has developed

a Sub-Regional Approach to the Pacific Islands (SAPI).

ACTIONS TAKEN

In 2019, a workshop was held to discuss a white paper outlining the concept and approach for sub-regional programming, and to agree on the way forward. The IAEA plans to finalize the Sub-Regional Approach for the Pacific Islands in the years 2020 and 2021, and to roll out its implementation through the development of sub-regional projects.

The SAPI was drafted upon careful review of current and past TC Programmes and Country Programme Frameworks in the Pacific Islands, and reflects common national issues and development aspirations of the Pacific Island countries.

It also addresses the desire of these countries to avail of advice and contribution from the IAEA technical cooperation programme to support development priorities in similar focus areas. This includes nutrition, agricultural productivity, non-communicable diseases like cancer, marine coastal environment, water resources management, and radiation safety.

In addition to the sub-regional approach, the IAEA also has Country Programme Frameworks (CPFs) with Fiji, Marshall Islands, Palau, Papua New Guinea and Vanuatu. So many national projects address a range of development priorities in these countries.

The IAEA plans to implement the Sub-Regional Approach in the Pacific Islands in three phases (see graph).

The sub-regional approach in the Pacific Islands will serve as a pilot framework for the delivery of technical cooperation assistance within several mutually-agreed, high-priority, focus areas.

The approach will place emphasis on indicators, baselines and targets that can be monitored using available and verifiable data.



A bustling marketplace in the island state of Palau (Photo: A. Wahid/Unsplash).

ACHIEVEMENTS

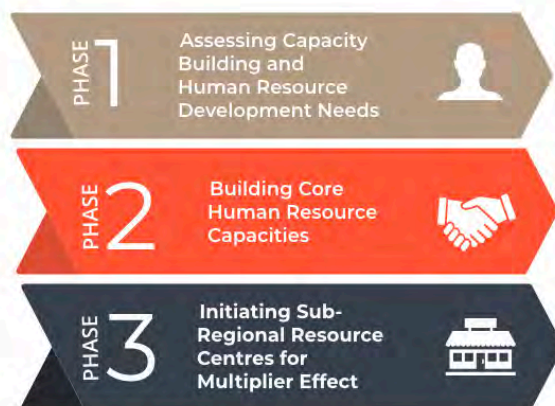
At present, the Pacific Islands need adequate institutional capacities to optimize the use of nuclear science and technology that are relevant to their priority areas for development.

The initiatives in the area of human resource development (HRD) are, therefore, a natural starting point for the IAEA's contribution towards ensuring that the Pacific Islands can use nuclear science and technology to attain their respective national development goals. In addition, HRD initiatives will greatly contribute to the availability of the competencies and skills that are needed to successfully plan, design, implement, monitor, and manage TC programmes and projects in the relevant sectors.

The national TC programmes of the Pacific Islands already provide the necessary transfer of knowledge and technology, so the proposed sub-regional approach will serve as an important complementary mechanism for greater effectiveness of these national programmes.

The sub-regional approach will help establish the core national human resource and, subsequently, the institutional capacities that would enable the Pacific Island Member States to improve their societies and economies. Through the use of nuclear science and technology they can achieve their development goals in areas such as nutrition, marine studies, water resources management, agricultural productivity and radiation safety infrastructure.

The Three Phases of the Sub-Regional Approach



PAKISTAN

MUTANT COTTON: A SUCCESS STORY

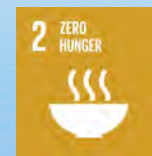


Photo: P. Maxwell 7123RF.com

THE SITUATION

Cotton is the most important cash crop and is known as the silver fibre of Pakistan. Cotton is mainly cultivated in the southern Punjab and Sindh regions bringing cash returns to the farmers, supplying raw materials to the textile industry and providing employment in both the rural and the urban areas.

Cotton provides a livelihood to over 5 million people in the farming industry and trade. It also furnishes raw material for ginneries, textile mills and oil expelling units in the country. The cotton seed harvest contributes to local edible

oil production. In addition, over 2 million tonnes of cotton oil cake is used as livestock feed. Thus, cotton plays a vital role in the country's economic development by contributing to the two major sectors: agriculture and industry.

Nationwide cotton production in 1948 was 0.1801 million metric tonnes. This increased up to 0.3241 million metric tonnes in 1961. Although Pakistan's cotton production had maintained a general upward trend since 1940s, the increase was slow and until the 1980s, overall production could only reach 0.591 million metric tonnes.

The yields were stagnant and due to the long maturity periods, wheat sowing was late resulting in a reduced harvest. Breeders were

unable to enhance yields and fibre attributes through conventional breeding due to the low genetic variability of the available germ plasm.

Women plucking cotton from the field (Photo: G.P. Ramchandani/123RF.com).



ACTIONS TAKEN

Foreseeing the potential of nuclear technology in food and agriculture and realizing the impact of the agriculture sector on the economic growth of the country, the Pakistan Atomic Energy Commission established its first agriculture institute in 1962.

The Nuclear Institute of Agriculture (NIA) was established at Tando Jam, Sindh with an irradiation source donated by the IAEA. Additionally, Pakistani scientists were trained in the induction, identification and selection of mutants.

The preliminary studies that were conducted proved to be of immense importance, not only in understanding the responses of different varieties and hybrids to radiation but also in finding out the workable doses and suitable genetic material for practical mutation breeding.

In 1972, a second agriculture institute was established at Faisalabad in the province of Punjab. This was done after taking into consideration the promising results at the NIA and the respective shares of the Punjab and Sindh provinces in cotton production — 81% and 19% respectively.

The new institute, called the Nuclear Institute for Agriculture and Biology (NIAB), was especially

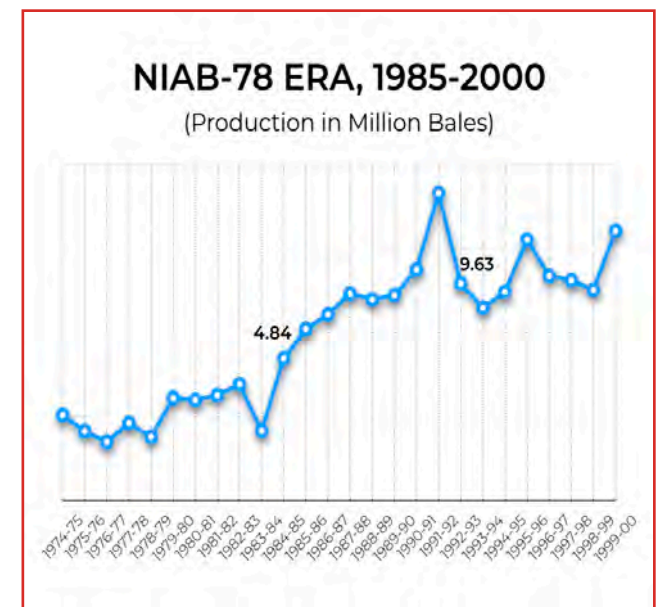
assigned the task of developing new cotton varieties as more than 80% of Pakistan's cotton area was situated in Punjab.

The first landmark achievement, through successful application of radiation mutation in cotton, was the development of the NIAB-78 cotton variety. NIAB-78 was developed by irradiating a derivative of F1 (AC-134 x Deltapine-16).

ACHIEVEMENTS

In 1983, NIAB-78 was approved by the Punjab Seed Council for general cultivation in Punjab. It was immediately accepted by the farming community, not only because of higher yields but because the early crop maturity induced through irradiation enabled the farmers to harvest their cotton fields for the cultivation of wheat well in time, (Farmer's Association Pakistan, 1984). With its exceptional adaptability and recovering capacity, NIAB-78 was soon cultivated in all provinces in the country. This versatile cotton variety stayed in the field for the longest period of time in the history of Pakistan.

By introducing this variety, the production of cotton in Pakistan increased from 4.84 million bales in 1983 to 9.63 million bales in 1991-92



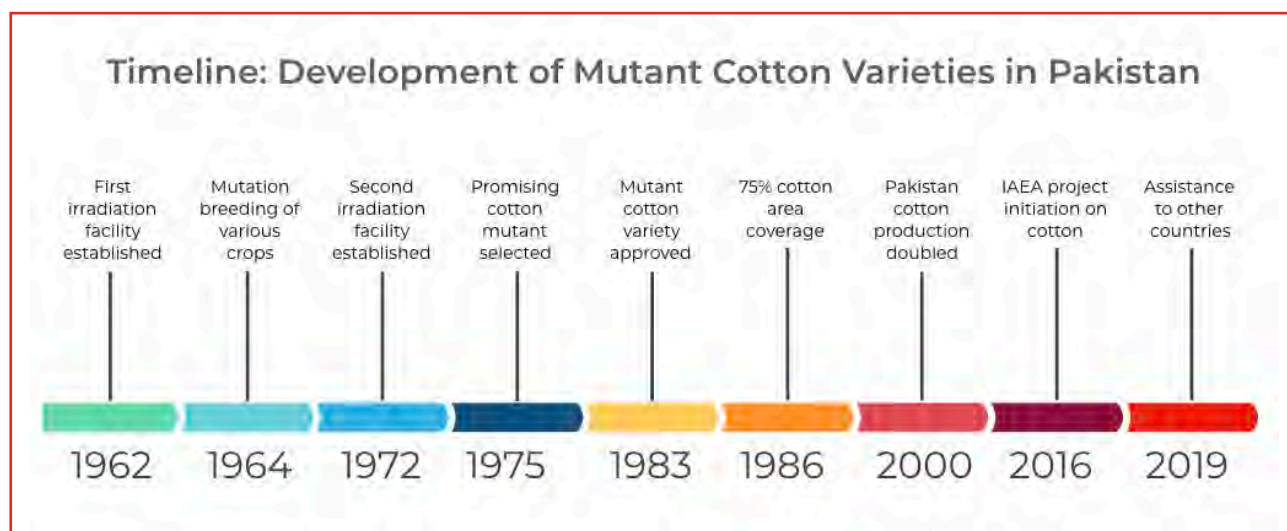
which is proof of the cotton revolution in Pakistan that has been brought about by NIAB-78.

With its overall goal of supporting NIAB in improving local varieties, the Joint FAO/IAEA Division in Nuclear Techniques in Food and Agriculture has included NIAB in regional projects for cotton in Asia. NIAB scientists serve as experts to support national and regional technical cooperation projects, and participate in the Joint Division's coordinated research projects.

In Pakistan, farmers have rapidly adopted mutant cotton varieties. These varieties are more resistant to pests and diseases and are able to withstand high temperatures and heavy rains.

It is estimated that 15%-25% of the total cotton area of the country is currently planted with mutant varieties, and the proportion is expected to increase by 30%-40% in the next few years. This positively affects, directly or indirectly, millions of stakeholders involved in the cotton industry.

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TERRITORIES UNDER THE JURISDICTION OF THE PALESTINE AUTHORITY

ESTABLISHING A LEGAL AND REGULATORY STRUCTURE



Photo: NERRA

However, in 2016, the legal and regulatory infrastructure to regulate and control these applications were not yet in place. The absence of national laws and regulations as well as the absence of an independent regulatory body were challenges that urgently needed to be addressed.

ACTIONS TAKEN

Since 2009, the Radiation Protection and Detection Unit (RPDU) has been working under the Ministry of Health. The RPDU was responsible for controlling the radiation protection in the peaceful applications of ionizing radiation. It also served as a service provider for personal and environmental radiation monitoring programmes.

RPDU was under the direction of allied medical services and hence did not have full authority in controlling upcoming practices. Its role was limited to giving recommendations to decision makers and the general licensing department under the Ministry of Health.

To be able to properly regulate and control the peaceful application of ionizing radiation especially in the medical field, top priority was given to improving the legal infrastructure and establishing an independent regulatory body.

High level decision makers requested all stakeholders represented by the national committee to work with the IAEA to begin reviewing the drafted national law on the peaceful application of atomic energy.

The national draft law entitled The Law of Peaceful Applications of Atomic Energy and Radiation Protection was reviewed by technical and legislative experts from different

THE SITUATION

Since 2013, the peaceful applications of atomic energy, particularly in the medical field, have increasingly been adapted in the territories under the jurisdiction of the Palestinian Authority. These include applications like nuclear medical diagnostic and treatment techniques.

Currently, only five nuclear medicine centres in the private sector offer diagnostic and treatment procedures using nuclear techniques like gamma camera, SPECT, PET-CT and I-131 thyroid cancer treatment.

Medical referrals outside the country cost the government more than 150 million dollars every year, which is a huge financial burden. Moreover, the patient and their relatives go through many difficulties when travelling for treatment abroad.

In 2016, nuclear medicine and radiotherapy were given top priority on the national level. As a result a national project to establish the Khalid Al-Hassan Hospital for cancer treatment and bone marrow transplant was announced. This hospital will also be the venue for the different nuclear medicine and radiotherapy applications to be introduced.



President Mahmoud Abbas approved and signed the national law in February 2018 (Photo: NERRA).

governmental entities. Another review by experts from the Jordanian Energy and Minerals Regulatory Commission took place through an official meeting arranged by the government.

The national law was approved and signed by President Mahmoud Abbas in February 2018.

National initiatives were also undertaken to establish an independent national regulatory body named the Palestinian Nuclear and Radiological Regulatory Authority (NERRA).

Careful measures were taken to guarantee the absence of crossover between NERRA and

A meeting at the IAEA on preparatory work for the establishment of the regulatory body (Photo: IAEA).



other government institutions with regards to functions and terms of references.

The IAEA played an important role all throughout the implementation of the national projects carried out under the technical cooperation programme.

Two national TC projects, in particular, contributed to support the national priority of the territories under the jurisdiction of the Palestine Authority. These projects are:

- * PAL9009: Upgrading the Regulatory Infrastructure for the Safety of Radiation Sources.
- * PAL6003: Building Capacity for Nuclear Medicine and Radiation Oncology for the Khalid Al-Hassan National Hospital.

Under TC project PAL9009, a meeting with IAEA experts was held in Vienna, Austria from 2–4 May 2018 to address the preparatory work needed for the establishment of the regulatory body of the territories under the jurisdiction of the Palestine Authority.

In this project, upgrading and qualifying the human resource requirements of the regulatory

ACHIEVEMENTS

Here are some of the achievements under the project:

- * The territories under the jurisdiction of the Palestine Authority's legal infrastructure was improved, the peaceful applications of atomic energy were regulated according to legal and regulatory base, and the national law was constitutionally approved;
- * Regulatory controls were established under the auspices of the national regulatory body, NERRA. National regulations have been drafted and are being reviewed;
- * A national inventory for radiation sources is being established using the Regulatory Authority Information System (RAIS) provided by IAEA;
- * Licensing and inspection programmes are being established; and
- * Human resource qualifications for NERRA are being improved.

body is also an ongoing process. In this context, training, scientific visits, meetings and workshops supported by the IAEA are being implemented or planned.

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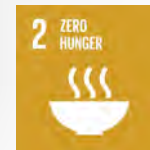


Photo: F. Sanchez /123RF.com



PHILIPPINES TURNING SEAWEED INTO A PLANT GROWTH PROMOTER

| THE SITUATION

Agriculture plays a very vital role in the Philippines archipelago. It accounts for 10% of the country's total gross domestic product and employs around 30% of the population.

One of the biggest challenges ever to confront Philippine agriculture is climate change. Its adverse impacts are already being felt and may intensify exponentially over time. According to the country's weather bureau, an average of 20 tropical cyclones develop in the region per year and about 8 or 9 of them cross the Philippines.

Recent natural disasters that have struck the Philippines – generally attributed to climate change – significantly affect crops and livestock, resulting in severe losses in human lives and agricultural production. These events have



More tropical cyclones enter the Philippine Area of Responsibility than anywhere else in the world (Photo: D. Pinzon/123RF.com).

worsened the economic situation and food security of the country.

There is, therefore, a critical need to develop climate-smart technologies and make them accessible to the farmers.

| ACTIONS TAKEN

Researchers from the Philippine Nuclear Research Institute (PNRI) developed the Carrageenan plant growth promoter (PGP), a radiation-modified carrageenan extracted from seaweeds.

Carrageenan is produced from the *Eucheuma* seaweed, a red algae grown in culture farms located mostly in the Eastern Visayas and Mindanao part of the Philippines.

The Philippines accounted for 46% of the world *Eucheuma* seaweed production in 2007, according to the Seaweed Industry Association of the Philippines.

The country remains the world's top producer of seaweed with an estimated production of 92 700 metric tonnes per year.

The PGP had its roots in IAEA project, RAS8109 (Radiation Processing of Polymeric Materials for Agricultural and Environmental Remediation) and a Forum for Nuclear Cooperation in Asia (FNCA) programme. This was implemented from 2009 until 2011 with the participation of 14 countries in the Asia region. The main goal of the project was to enhance agricultural production and mitigate environmental pollution using radiation technology.

From 2009 to 2013, R&D and small-scale production of PGP were conducted at two PNRI facilities: the Chemistry Laboratory and at the Multi-Purpose Gamma Irradiation Facility. Field experiments of the product on rice started in 2012, through a USD400 000 grant from the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development in the Department of Science and Technology. The field trials were done in partnership with other government agencies, most notably, the Philippine Rice Research Institute and Laguna National Crop Protection Center of the University of the Philippines in Los Baños.

However, PNRI's Gamma Irradiation Facility could produce PGP only at a rate of 1200L every 4 days, which is barely enough to cover 133 hectares of rice fields. This throughput is not feasible for the production of the PGP on a commercial scale.

PNRI needed an ebeam facility to make Carrageenan PGP commercially viable. The establishment of an Electron Beam Facility in PNRI was brought about through two TC projects – PHI8026 (Establishing an Electron Beam Facility) and PHI1017 (Using E-beam Technology for Industrial, Environmental and Agricultural Applications). These projects helped pave the way for PGP's potential commercialization.

The IAEA, together with donor countries China, Japan, and USA contributed 1/3 of the total facility cost under the IAEA's Peaceful Uses



Rice crops sprayed with Carrageenan PGP withstood the devastating typhoon “Lando,” while nearby ricefields without Carrageenan PGP experienced lodging (Photo: VITALGRO).

Initiative. The Philippine government covered the remaining cost.

Today, an 8-hour daily production of the PGP using the ebeam facility can yield up to 13 600L (1700L/hr.) which can cover 1500 hectares of rice fields.

ACHIEVEMENTS

Dr Lucille V. Abad, PNRI scientist and lead inventor of the Carrageenan PGP, and the entire research team have been the recipients of extensive local and international recognition.

The PGP product demonstration with farmers in 2015 and the multi-locational trials covering approximately 40 000 hectares showed the following:

- * Consistent increase in harvest yield by an average of 20%,
- * Increased in number of tillers,
- * Resistance of plant to tungro virus,
- * Extensive root growth and sturdy stems, all showing enhanced crop production and resilience to climate change.

For the positive impact of PGP to be felt by the more than 100 million Filipinos, the product has

to be easily accessible to the farmers. In 2017, PNRI registered the PGP as a product with the Philippines Fertilizer and Pesticide Authority. It also signed technology transfer agreements with three companies and submitted a patent application.

In 2018, two of the three companies paid the license fees, paving the way for commercialization of PGP. In the same year, field trials for mungbean and peanuts began and showed yield increases of up to 35% and 40%, respectively. The PGP is also being continuously tested on other crops for further label expansion.

In 2019, one company kicked-off its direct selling strategy bringing PGP directly to local rice producers. The second company, meanwhile, launched the product in the market under the brand, VITALGRO Carrageenan. Today, PNRI's Carrageenan PGP is selling in the Philippines at a price affordable to ordinary Filipino farmers.

Indeed, nuclear science is working for the Philippines and its people.

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QATAR

DETECTING RADIOACTIVE CONTAMINANTS IN FOOD IMPORTS

THE SITUATION

Qatar is highly dependent on imported food from many countries. The Central Food Laboratories (CFL) is the country's only food testing laboratory. Operated by the Ministry of Public Health, it works with the border control points of Qatar to ensure that imported food is analysed and free from harmful radioactive contamination in compliance with the permitted radioactivity levels established by national regulations. This applies to all imported drinking water as well.

Increased cancer cases around the world and particularly in the Gulf area have heightened the demand for a more accurate technique in detecting contamination in food and drinking water samples.

Taking this into consideration, the CFL proposed a shift of its analytical capabilities to gross alpha/beta contamination detection technique. It also proposed to set up a radiochemistry separation laboratory for detecting alpha NORMs using an alpha analyser along with a gas proportional counter for detecting alpha and beta emitters quantitatively.

NORMs are naturally occurring radioactive materials such as polonium-210, uranium-238, thorium-228, etc. which can sometimes be found in food and water samples.

However, CFL was unable to carry out these changes on its own. It first needed the IAEA's support in objectively evaluating the laboratories' capability and in recommending necessary measures to enable CFL to meet the requirements of international accreditation standards.



Photo: Qatar Ministry of Public Health

ACTIONS TAKEN

Two IAEA technical cooperation projects, QAT5004 (Upgrading the Central Food Laboratory) and QAT5005 (Upgrading the Central Food Laboratory Phase II), were implemented during 2014-2015 and 2016-2017, respectively, to upgrade the central food laboratory.

Under these projects, the physical infrastructure of the laboratories was upgraded and the procedures were developed for the screening

and testing of imported food and drinking water using a liquid scintillation counter.

These activities enabled the laboratories to determine the presence of gamma and alpha-emitting contaminants qualitatively. Another aim was to establish a radiochemistry separation laboratory for using alpha spectroscopy system to measure the concentration of alpha emitting radionuclides in seafood. At the same time, a gas proportional counter for measuring alpha and beta concentrations of different isotopes was installed.

The two projects were successfully implemented, including fellowships, scientific visits and other activities in the work plan of each project cycle.

In 2017, the CFL received international accreditation with an ISO 17025 certification in two methods for gamma measurements. The first method is screening of Cs-137 gamma emitting radionuclides using thallium-doped sodium iodide NAI (TI) scintillation spectroscopy. The second method is determination of gamma ray emitting radionuclides using high purity germanium (HPGe) gamma spectroscopy.

The work on having ISO accreditation of two more methods is ongoing. The first method is detection of gross alpha/beta emitting radionuclides in drinking water using a liquid scintillation counter (LSC) and the second method is detection of polonium-210 in seafood using alpha spectrometer.



Photo: Qatar Ministry of Public Health

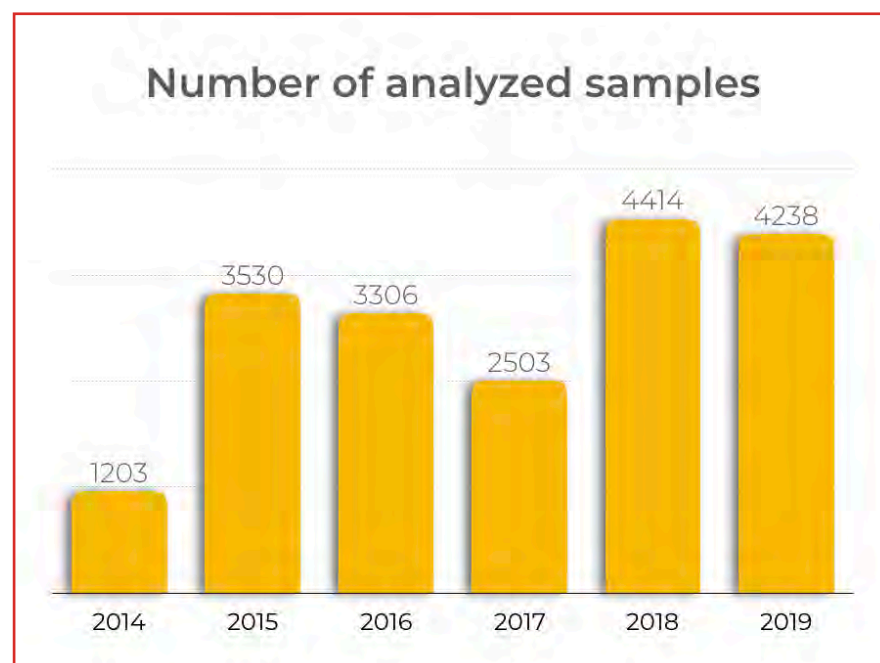
ACHIEVEMENTS

The experts in Qatar's Central Food Laboratories have significantly improved their skills in radiation measurements through human resource

development activities supported by the IAEA. This includes using LSC in measuring gross alpha/beta concentration activities in drinking water; establishing a radiochemistry separation laboratory for using an alpha spectroscopy system to measure the concentration of alpha emitting radionuclides in seafood; and establishing a gas proportional counter for measuring alpha and beta concentrations of different isotopes.

Medical Corporation is utilizing the laboratory data to serve their hospital patients.

Around 3000–4000 food samples are analysed each year and there is a yearly increase in the number of tested samples. With such a high level of technical expertise, the laboratory is able to provide high quality services to different customers, stakeholders and the general public. The laboratory is running at full capacity and the rate of food sample testing is increasing every year.



Benefiting directly from the new techniques are the local municipalities, the Hamad Medical Corporation, and the Environmental Health and Port Health sections which are CFL's main customers.

Today, imported food samples can be more precisely monitored for the permissible levels of all the contaminants. The Ministry of Municipalities and Environment receives the reports to evaluate the data with respect to radiation legislation while Hamad

Through its use of the most modern technology available and, with the IAEA's support, CFL received ISO 17025 certification. This enables CFL to demonstrate that it operates competently and generates valid results, thereby promoting confidence in its work, both nationally and around the world.

Qatar also fulfilled its objective to ensure that only the highest quality of food are sold in local markets for public consumption and for business continuity.

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SAUDI ARABIA

PROGRESS IN THE NUCLEAR ENERGY PROGRAMME



governance and oversight structure, separate from other initiatives, and officially launched as the Saudi National Atomic Energy Project (SNAEP), with support from HRH Prince Abdulaziz bin Salman bin Abdulaziz Al Saud, Minister of Energy, and HRH Prince Abdullah bin Khalid bin Sultan, Saudi Arabia's Ambassador to Austria.

Since it is a newcomer country to nuclear energy, Saudi Arabia has maintained strong cooperation with the IAEA for assistance in developing all key components of SNAEP. This led to the adoption of the IAEA's Milestones Approach as the framework for design and implementation of SNAEP, with K.A.CARE serving as the Nuclear Energy Programme Implementing Organization.

ACTIONS TAKEN

THE SITUATION

Saudi Arabia has experienced dramatic growth and development over the last decades. This has driven rapid growth in domestic energy consumption that is expected to continue into the future to power Saudi Arabia's ambitious development plans. The need to diversify the national energy mix from complete dependence on fossil fuels to one that includes nuclear and renewable energy was thus recognized by the Government, and led to the creation of the King Abdullah City for Atomic and Renewable Energy (K.A.CARE) in 2010.

With this mandate, K.A.CARE worked on developing plans for introducing nuclear energy and establishing the required national infrastructure. The efforts gained substantial momentum in 2016, with the launch of the



Saudi Arabia and the IAEA meet yearly to update the Integrated Work Plan for the development of nuclear power infrastructure for 2020–2023 and beyond.

Nuclear Energy Programme as part of the National Transformation Programme and Saudi Arabia Vision 2030 Programme, which aims to diversify the country's energy base, create a competitive energy sector, and reduce the reliance on fossil fuels. In July 2017, the nuclear energy programme was given a high-level

Through the Integrated Work Plan, K.A.CARE carried out a series of activities which addressed various infrastructure elements according to the IAEA's milestone approach. As part of that, K.A.CARE conducted a self-evaluation of the national infrastructure for nuclear power based on the IAEA Nuclear Series publication Evaluation of the Status of National Nuclear Infrastructure Development (NG-T-3.2 (Rev. 1) against Phase 2 conditions.

An INIR mission also took place in July 2018, and concluded that Saudi Arabia has made significant progress in the development of its nuclear power infrastructure. The peer review mission also identified several good practices that may benefit other countries that are considering the introduction of nuclear power.

To coordinate the continued development of the infrastructure required throughout the three



The INIR team's preliminary draft report being handed to Dr Khalid Al Sultan, K.A.CARE President, at the end of the INIR mission in Riyadh on 24 July 2018 (Photo: K.A.CARE).

phases of the Milestones Approach, K.A.CARE established the National Nuclear Infrastructure Development (NNID) Programme as a systematic implementation framework for coordination, oversight, monitoring and reporting activities.

The NNID Programme's main objectives include delivering a National Action Plan that covers all necessary infrastructure activities, coordinating its implementation with all key stakeholders.

This Action Plan will serve as a roadmap to ensure that infrastructure development activities are aligned and managed in an integrated manner for the delivery of Saudi Arabia's first nuclear power plant.

IAEA support has helped Saudi Arabia make improvements through the NNID Programme, which has a defined governance and execution structure. Its technical cooperation projects with the IAEA have contributed to developing Saudi Arabia's nuclear infrastructure, providing much needed support to the nuclear power programme, its regulatory aspects, as well as emergency preparedness and response.

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TC projects providing IAEA support to Saudi Arabia's nuclear power programme

Project Code	Title	Date
SAU2007	Developing Infrastructure for the Introduction of a Nuclear Power Programme (Phase II)	2016–2017
SAU9009	Supporting the Programme of the National Regulatory Infrastructure for Nuclear and Radiation Safety: Nuclear Power Phase	2016–2017
SAU9010	Enhancing Capacity Building in Radiological and Nuclear Emergency Preparedness and Response	2016–2017
SAU2009	Developing the Infrastructure for the Nuclear Power Programme	2018–2020
SAU9011	Supporting the Implementation of the Regulatory Body and the Development of Nuclear Regulators	2018–2021
SAU2010	Developing the Infrastructure for the Nuclear Power Programme	2020–2021

ACHIEVEMENTS

Through support it received from the TC projects, Saudi Arabia was able to advance through phases 1 and 2, and achieved several milestones such as supporting the development of the nuclear regulator, and the issuance of important national instruments as summarized in the figure below. This include the issuance of the National Policy for the Atomic Energy Programme of the Kingdom of Saudi Arabia in March 2018; issuance of the Statute of the Nuclear and Radiological Regulatory Commission, also in March 2018; issuance of the Law of Nuclear and Radiological Control, and the Law of Civil Liability for Nuclear Damage, both in April 2018.

Saudi Arabia will continue its close collaboration with the IAEA through its technical cooperation programme to improve through the planned milestones beyond 2020.



SINGAPORE

DEVELOPMENTS IN RADIATION MONITORING AND NUCLEAR MEDICINE



ACTIONS TAKEN

Radiation Monitoring. Via its national TC programme, Singapore has worked with the IAEA to build its capability in the areas of radiochemistry, specifically in the analysis of environmental samples. The country's training activities included scientific visits and attachments to overseas laboratories, including those under the IAEA, Australian Radiation Protection and Nuclear Safety Agency, Technical University of Denmark, and France's Institute for Radiological Protection and Nuclear Safety.

Singapore also participated actively in many regional and national projects in the field of radiation monitoring. Through the series of regional workshops and trainings, Singapore has further honed its technical knowledge and skills in radiochemistry and radioanalytical techniques for the analysis of radionuclides in both the terrestrial and marine environment.

Nuclear Medicine. To develop local capability in the area of nuclear medicine, Singapore has participated in numerous, regional IAEA technical cooperation projects in the field of nuclear medicine, including those under RCA projects (*see table next page*).

Under the TC national projects, Singapore took part in several scientific visits and training courses in topics such as radiopharmaceutical production, radiopharmaceutical applications and diagnostic radiology to further develop its capability in nuclear medicine.

THE SITUATION

Radiation Monitoring. The Fukushima nuclear power plant accident in 2011 highlighted the potential transboundary impact of a nuclear incident and the need for radiation monitoring at the state level.

Prior to 2011, Singapore did not have a radiation monitoring programme nor a dedicated laboratory to analyse radioactivity levels in environmental samples. These capabilities are important for early detection and to enable the country to apply appropriate protective measures in a timely manner, in case of any release of radioactive substances during an incident that may cause transboundary impacts.

Nuclear Medicine. Nuclear medicine is a specialized field that involves the use of radiopharmaceuticals in conjunction with highly specialized imaging instrumentation to assess physiological processes, diagnose and treat diseases, measure distribution of drugs, and monitor treatment effectiveness.

The field of nuclear medicine has evolved over the years as evident in advancements in imaging instrumentation, radionuclide production, and radiopharmaceutical development. To ensure its continued success, the workforce needs to keep abreast with evolving trends and undergo continuous training to build capabilities and remain relevant.

Active National and Regional Technical Cooperation Projects (as of 2020)

Project*	Title	Area	Type
SIN0003	Building Capacity in Nuclear Power Technology and Safety	Nuclear Power Technology, Nuclear Safety	National Project
SIN6006	Building up Expertise and Capability in the Application of Proton Therapy	Radiation Oncology	National Project
SIN9026	Strengthening the Regulatory Infrastructure for Radiation Protection and Transport Safety	Radiation Protection	National Project
SIN9027	Strengthening Capacities in Emergency Preparedness and Response, and Radiation Monitoring	Radiation Monitoring, Emergency Preparedness and Response	National Project
RAS6093	Strengthening Capacity to Manage Non-Communicable Diseases Using Imaging Modalities in Radiology and Nuclear Medicine (RCA)	Nuclear Medicine	Regional Project
RAS6091	Enhancing the Management of Non-Communicable and Communicable Diseases through Capacity Building under the IAEA Curricula for Nuclear Medicine Professionals	Nuclear Medicine	Regional Project
RAS6090	Promoting the Preparation of Emerging Radiopharmaceuticals for Positron Emission Tomography-Based Molecular Imaging and Radionuclide Therapy	Nuclear Medicine	Regional Project
RAS7028	Enhancing Regional Capabilities for Marine Radioactivity Monitoring and Assessment of the Potential Impact of Radioactive Releases from Nuclear Facilities in Asia-Pacific Marine Ecosystems	Radiation Monitoring	Regional Project

* This is not a complete list. Singapore also participates in 22 regional and 2 interregional projects, mostly in the area of health and nutrition, and water and the environment.

In addition to the area of nuclear medicine, Singapore is also developing capacity in advanced radiotherapy technique (proton beam therapy). The first proton beam therapy facility in the country is being established and is expected to be in operation in 2022.

Within the last several cycles, Singapore has also developed national capability in radiation protection and radiation monitoring in both terrestrial and marine environment, as well as in emergency preparedness and response.

ACHIEVEMENTS

Radiation Monitoring. Singapore's efforts to build up its capability in the area of environmental radiation monitoring have paid off. The National Radiochemistry Laboratory (NRL) was successfully set up in 2017 and started operations in early 2018.

In 2018 and 2019, NRL participated in the annual IAEA World-Wide Proficiency Test on

Determination of Anthropogenic and Natural Radionuclides in Water and Soil samples. NRL performed well in both tests where their results met the criteria for all the reported radionuclides in terms of accuracy and precision. It has since – from May 2019 – become a member of the IAEA ALMERA network.

Currently, Singapore has a core team of six scientific officers to drive the environmental baseline radiation monitoring programme. In two to four years, it hopes to continuously improve NRL's technical competencies in detecting a wide range of radionuclides, with better detection sensitivity and selectivity of radionuclides of interest. It also aims to attain ISO17025 accreditation for its laboratory.

Singapore looks forward to IAEA's continued support to further develop its capabilities in radiation monitoring.

Nuclear Medicine. Singapore has benefited from the IAEA TC programme in developing its local capability in nuclear medicine. Since

the establishment of the Country Programme Framework (2016–2020), Singapore has been able to take part in numerous activities held under IAEA projects in the area of nuclear medicine.

Through training courses, fellowships and scientific visits, Singapore was able to acquire more knowledge and expertise in nuclear medicine. For example, the staff at Singapore General Hospital has been updated on new applications and new tracers used in SPECT-CT for relevant conditions. This has greatly improved the hospital's clinical decision making.

Through the development of local capability in nuclear medicine, Singapore was also able to contribute to regional projects by sending experts overseas as trainers and hosting workshops in the country. For example, in June 2019, the Singapore General Hospital hosted the IAEA Regional Training Workshop on Production, Quality Control and Health Regulations for Radiopharmaceuticals.

Singapore looks forward to IAEA's continued support for the continuous development of its capabilities in nuclear medicine.

In 2015, the IAEA and the Government of Singapore signed a Memorandum of Understanding on a Singapore-IAEA Third Country Training Programme. Singapore's expertise across a wide range of areas, including nuclear medicine, nuclear safety, public education, industry and the environment, has enabled it to work closely with the IAEA on building regional capacity through south-south and triangular cooperation.

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SRI LANKA

ESTABLISHING A ROADMAP FOR A NUCLEAR POWER PROGRAMME

THE SITUATION

Ceylon Electricity Board's 20-year Long Term Generation Expansion Plan (LTGEP) considers nuclear power as a potential future power generation alternative for Sri Lanka. In addition to the Business as Usual plan, a number of other scenarios and sensitivity analysis are included in the LTGEP to facilitate the decision-making process on selecting the best generation infrastructure development strategy for the country in the next 20 years.

In the LTGEP, various energy mix scenarios are evaluated for the possible energy supply alternatives. The latest approved LTGEP explores the nuclear power option in an enhanced energy mix scenario, to be developed along with hydro, thermal and other renewable energy sources.

According to the analysis, the first nuclear power plant is considered to be built beyond 2030. This will be continuously updated with longterm generation planning process considering sufficient lead-time to implement nuclear power related studies and activities.

Unlike other thermal power projects, a nuclear power plant requires comprehensive studies on associated infrastructure issues. Developing the national infrastructure for a successful introduction of nuclear power requires many activities. These are laid out as a guide to newcomer countries in the IAEA Milestones Approach.

A comprehensive analysis of the issues laid out in the IAEA Milestones Approach to new nuclear power programmes needed to be undertaken before Sri Lanka can make a knowledgeable



National Workshop on Nuclear Power Technology and Nuclear Power Education and Training, 10–12 December 2018 (Photo: Sri Lanka Atomic Energy Board).

commitment to a nuclear power development programme.

ACTIONS TAKEN

A national project concept was developed for Establishing a Roadmap for the Nuclear Power Programme in Sri Lanka and submitted to the IAEA TC cycle for 2018–2019 as TC project SRL2010.

IAEA expert assistance was also sought to initiate Phase 1 of the IAEA Milestones Approach by addressing the 19 nuclear infrastructure issues. The expected project outcome would be to come up with a sound, scientific basis for policy makers to make decision on nuclear power development in Sri Lanka, taking into consideration the technological, financial, environmental and social issues.

Expected project outputs would include:

- * The establishment of a Programme Management Unit, including a Steering Committee, a Team Leader and Nine Working Groups;
- * Preparation of a comprehensive report addressing the 19 nuclear infrastructure issues defined by IAEA by the end of 2020.

Regular meetings were conducted with the participation of the team leader, working group leaders and members to monitor the progress of the preparation of individual reports. Several Steering Committee meetings were conducted at the Ministry of Power and Energy to monitor the progress of the programme.

IAEA Expert Assistance

IAEA assistance is being provided in nine major areas to prepare the comprehensive report that

IAEA workshops to raise awareness of the issues to be addressed for nuclear power development

Workshop Title	Date
National Workshop on Introducing the 19 Infrastructure Issues for Nuclear Power Programme Development for Sri Lanka	16–19 July 2018
Workshop on 19 Infrastructure Issues for Nuclear Power Programme Development for Sri Lanka (National Position, Human Resource Development & Security)	3–5 October 2018 8–10 October 2018
National Workshop on Nuclear Power Technology and Nuclear Power Education and Training	10–12 December 2018
National Workshop to support the Development of a Policy and Strategy on Industrial Involvement	11–13 June 2019

covers the 19 nuclear infrastructure issues from the IAEA Milestones Approach.

The IAEA held several workshops with the objective of raising awareness on the role, responsibilities, necessary actions and scope of study on the nine major areas required for successful implementation of the project (see table).

Several other expert missions were conducted in 2019 with the participation of experts in nuclear industry and related fields.

The 19 Nuclear Infrastructure Issues in the IAEA Milestones Approach



ACHIEVEMENTS

As a result of the project, officials of counterpart institutions, as well as other stakeholders and partner institutions, gained knowledge of the 19 nuclear infrastructure issues in nuclear power development. Individual working group reports are being prepared that would identify the scope of the project's first phase.

These in-depth reports would guide policy makers in making a knowledgeable decision on the nuclear power programme.

For the different sectors in Sri Lanka, the project benefits are expected to be as follows:

For the General Public. The project will evaluate infrastructure requirements for new electricity generation options that would meet future electricity demand. The project could help reduce the cost of electricity due to low cost generation. It will also diversify the economies of the

rural communities and create short- and long-term job opportunities by providing new types of income.

Policy Makers/Government. The project will contribute towards the economic development of Sri Lanka and reduce its dependency on high cost petroleum fuels and the associated heavy financial burden on the government.

Electric Utility. The project will give utilities the opportunity to carry out further studies based on the factors identified by the study.

Regulatory Authorities. The project will help identify the legal and regulatory requirements for licensing and monitoring of a nuclear power plant through all stages – planning, construction, commissioning, operation and decommissioning.

All other Stakeholders. Other stakeholders can enhance their knowledge of the milestone approach to the nuclear power programme as it relates to their own expertise.

Overall, the project's positive impact so far was to provide Sri Lanka with a scientific approach to studying the 19 nuclear infrastructure issues so that policymakers can make informed decisions. The project also initiated a change in the overall thinking on nuclear power through knowledge sharing among stakeholders.

And, finally, by evaluating infrastructure requirements on new electricity generation options, the project could help give Sri Lanka an energy mix that would meet future electricity demands.

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SYRIAN ARAB REPUBLIC

MONITORING VETERINARY DRUG RESIDUES IN FOOD



as Syria seeks to collaborate with existing or related IAEA technical cooperation projects.

As a result, and in line with its national development plan for 2016, Syria established a technical cooperation project (SYR5024) which aimed to enhance food and animal feed safety to mitigate the risk to human beings, animals and the environment.

The project also sought to achieve the following:

- * To set up a laboratory capable of detecting various types of residues and assessing the risk of the tested and other compounds to human health;
- * To train the staff on how best to perform and apply the methodologies and technologies; and
- * To assess the abuse of the tested and other compounds, and improve public health.

ACTIONS TAKEN

The following actions were taken under the technical cooperation project, SYR5024:

- * Establishment of a laboratory capable of monitoring and detecting various types of residues,
- * Screening and monitoring of selected compound residues; and
- * Assessment of the risk of the tested compounds on human beings, animals and the environment.

The project strategy was as follows:

- * The laboratory was equipped with an enzyme-linked immunosorbent assay (ELISA) reader and related kits for

THE SITUATION

The food and agriculture sector is one of the top priority areas in Syria. There is growing concern about the dangers of veterinary drug residues (including, but not limited to, natural and synthetic hormones, antimicrobial agents, anthelmintic agents, antiprotozoal agents, growth promoters, beta agonists, etc.) on human health, as well as an urgent need for screening programmes to ensure that animal products used for human consumption are free from residues of any type.

But such programmes and methodologies were previously not available in Syria. The

few studies that were done mainly addressed steroid hormones, such as progesterone and testosterone, using blood plasma or serum.

Syria, therefore needed a programme that would expand both the number and types of materials to be assessed. The programme would leverage existing partnerships and enhance relations with institutions such as the Radiation Technology Department and the private industry, including importers.

A number of Syrian government ministries, such as the Health and Agriculture, Higher Education and Internal Trade and Consumer Protection ministries, have a special interest in such a programme. Their involvement is important

rapid screening of contaminants. Other equipment included a multi gamma counter, homogenizer, rotary evaporator, centrifuge, balances, mixers, pipettes, and chemicals, which were received through the IAEA.

- * A Veterinary Drug and Growth Promoters Laboratory was established by the Atomic Energy Commission of Syria (AECS) with basic glassware and consumables.
- * Capacity building was enhanced through six fellowships and nine scientific visits.
- * Different stakeholders were engaged in the project implementation process. Close collaboration was maintained with the General Commission for Scientific Agricultural Research. The Ministry of Agriculture, meanwhile, provided the animals needed for testing experiments.

The project aimed to benefit the Syrian people, the livestock industry and the environment.

ACHIEVEMENTS

Food and feed safety in Syria improved remarkably with the implementation of the technical cooperation project, SYR5024.

In 2017, a laboratory specializing in veterinary drug residues and in the analysis of growth promoters was set up at the Department of Agriculture, Atomic Energy Commission in the capital Damascus.

This laboratory is equipped with related equipment, basic glassware, chemicals, consumables and other materials. In future, this laboratory is expected to serve as the regional laboratory.

HPLC-UV/VIS Technique. In 2018, the high performance liquid chromatography with ultraviolet/visible (HPLC-UV/VIS) technique was introduced and laboratory staff were trained accordingly on its use.



Top and below: The laboratory for Naturally-Occuring and Synthetic Anabolic Hormones and Veterinary Drug Residues in Animal Products and Feeds with basic equipment, glassware and consumables (Photo: M. Zarkawi/ AECS).

In 2019, the laboratory started analysis of the antibiotics, Tetracycline, Oxytetracycline, chlortetracycline, in liquid milk samples according to the Ullah et al. 2012 method.

Since there is very little or no regional information available on growth hormones and veterinary drug residues in feeds and food, the results and outcomes of the project can be shared with other countries in the region.

The information can possibly also be shared with international organizations, such as the Food and Agriculture Organisation (FAO) of the United Nations, the World Organisation for Animal Health (OIE), and the World Health Organisation (WHO) for further dissemination. Project results and outcomes can likewise



be presented in meetings, seminars and conferences, and published in international peer reviewed journals.

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THAILAND

RADIATION PROCESSING: FROM LABORATORY TO MARKET



Photo: Tomwal / 123RF.com



Photo: D. Chulay / 123RF.com



THE SITUATION

Many universities in Thailand offer curricula relating to radiation sciences and applications. These universities possess the right combination of competent teaching staff and students. Some of them even have state-of-the-art laboratories.

The primary goal of these universities is to educate students and guide them toward professional degrees in this field. Academic excellence in the form of journal publications and conference proceedings are often, if not always, used as measures of success.

The Center of Radiation Processing for Polymer Modification and Nanotechnology (CRPN) at Kasetsart University, Thailand is piloting a different approach. Under an IAEA technical

cooperation project, Kasetsart University intends to bring the benefits of using radiation technologies to people beyond the laboratory. This is in line with the objectives set forth by the IAEA technical cooperation programme which

The skyline of Thailand's capital city of Bangkok.



Photo: W. Tonkun / 123RF.com

looks for tangible outcomes that can contribute to national growth and development.

ACTIONS TAKEN

The IAEA technical cooperation project (THA1010) was designed to enhance the use of radiation processing for polymer modification in agriculture and industry. In addition to strengthening the educator's role, the project also aimed to transfer the results of laboratory research to the private sector for industrial scale production.

Various activities helped to achieve the project's outcome. Expert missions, scientific visits and fellowships served as effective vehicles for the transfer of knowledge in the application of nuclear science and technology to the country for use in domestic development. Procurement

of modern equipment also contributed to improved laboratory capabilities.

The project was methodically designed to provide necessary knowledge and experience to the national project team.

This ranged from fundamental to advanced skill levels in the area of radiation processing. The national team was then able to extend its knowledge and expertise to existing industrial partners like the following:

- * Mitr Phol Sugar Corp. Ltd. (Sugar production company);
- * PTT Public Co. Ltd. (Petroleum and petrochemical company);
- * Anwill Co. Ltd. (Ink production company);
- * Ideol Digital Print (Print company); and
- * Charoen Pokphand Foods Public Co. Ltd. (Food and chain store company).

ACHIEVEMENTS

The Center of Radiation Processing for Polymer Modification and Nanotechnology (CRPN) was established and provided the technical know-how through TC project, THA1010.

The CRPN will be promoted as a Specialized Centre at the Department of Materials Science, Faculty of Science, Kasetsart University.

The CRPN acts as a national academic centre to sustain and transfer knowledge and technology to students, scientists, researchers, as well as the industrial sector in Thailand.

Several publications were published as a result of the project, including:

- * 'Electron beam induced water-soluble silk fibroin nanoparticles as a natural antioxidant and reducing agent for a green synthesis of gold nanocolloid', Soraya



The Office of Atoms for Peace in Bangkok serves as the main authority for nuclear research in Thailand. (Photo: Thailand Office of Atoms for Peace)

Wongkrongsak, Theeranan Tangthong and Wanvimol Pasanphan, Radiation Physics and Chemistry 118 (2016), 27-34

- * 'Piperidine-conjugated polyfunctional star-shaped PLLA as a novel bio-based antioxidant additive for bioplastics', Kamonwan Haema, Thananchai Piroonpan, Saowaluk Taechutrakul, Anan Kempanichkul and Wanvimol Pasanphan, Polymer Degradation and Stability (2017), 145-154

At the same time, a national patent on the production of antioxidant additive from a polyfunctional, star-shaped polylactic was granted and several product prototypes were also developed.

These included the following:

- * Nanogels and hydrogel for agricultural applications, for example, release-controlled fertilizer; water retention; and smart farming;
- * Coating/Printing/Packaging including a water resistant agent; a coating bioplastic agent, and an agent for inhibiting growth in molds; and
- * Bioplastic products.

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UNITED ARAB EMIRATES

SUPPORTING A MODEL NUCLEAR NEWCOMER



THE SITUATION

Nuclear Power. In 2008 the United Arab Emirates (UAE) embarked on its peaceful nuclear energy programme for electricity generation, committing to the highest standards of safety, security and non-proliferation, and to working transparently with the IAEA to that purpose.

Radiation Safety infrastructure. When the UAE embarked on its nuclear programme, a significant challenge was to bridge the identified gaps in the country's radiation safety infrastructure, and to promote positive, coordinated enhancements in themes as diverse as medical practice, the standardization of protocols for service providers, the transport of radioactive materials, etc.

Analytical and Dosimetry Capabilities. The UAE had no national laboratories answering the country's needs in calibration of radiation



measurement instruments, for the medical and industrial sectors or to support needs of the nuclear power programme under development. It used to send all instruments for calibration abroad, which was both costly and time consuming.

Materials Analysis Capabilities. The UAE had little local capabilities for non-destructive material analysis to address rising

demands in sectors of archaeology, cultural heritage, forensics, industrial materials, and environmental monitoring. Because of its regional nature, the problem of the long-range transport of fine particulates needed to be addressed through aerosol mapping and identification of pollution sources and transport across borders.

ACTIONS TAKEN

Nuclear Power. Through a series of well-planned TC projects, and an Integrated Work Plan (since 2013) which covers all aspects of nuclear infrastructure and HR development, the UAE worked closely with the IAEA to build its capacity in all 19 elements of the Milestone Approach.

All projects involve all relevant national nuclear stakeholders including: the UAE Permanent Mission to the IAEA, Federal Authority for Nuclear Regulation (FANR), Emirates

TC Projects in Nuclear Power Infrastructure

Project	Objective	Years
UAE9008	Provide preliminary support for development of national nuclear power infrastructure for electricity generation	2010–2011
UAE2003	Provide concrete technical and experts' assistance in establishing and strengthening the NEPIO and national stakeholders	2012–2015
UAE2004	Continue to support the UAE to successfully accomplish the transition from construction phase to the operational phase for the Barakah nuclear power plant	2016–2019
UAE0007	Contribute to the sustainability of UAE peaceful nuclear energy programme through a robust capacity building programme for the national workforce	2018–2021

Nuclear Energy Corporation (ENEC), National Emergency, Crisis and Disaster Management Authority (NCEMA), and various ministries. Additional projects have complemented the efforts of the ones mentioned, through dedicated attention to radioactive waste management, environmental monitoring related to nuclear power plants, and preparedness and response for nuclear and radiological emergencies.

Radiation Safety infrastructure. Through consistent collaboration with the IAEA, significant progress has been made in all relevant areas of radiation safety, and in the interface between nuclear safety, security and safeguards. A series of national TC projects channeled technical support to national stakeholders and allowed the enhancement of radiation safety services, practices and standards in the UAE to international level.

These projects supported the procurement of equipment and human resource development (HRD) through workshops and expert missions. The current project, UAE9012, channels comprehensive IAEA support to strengthen the infrastructure for radiation, transport and waste safety. Under it, more than 26 activities provide IAEA assistance in reviewing national regulations and guides, organizing national workshops and training.

TC Projects in Radiation Safety Infrastructure

Project	Objective	Years
UAE9008 UAE2003 UAE2004	Focused on enhancing radiation and nuclear safety as part of the UAE nuclear power infrastructure	2010–2011 2012–2015 2016–2019
UAE3003 UAE3004 UAE9009 UAE9010	Focused specifically on enhancing UAE's radioactive waste management	2007–2009 2009–2011 2012–2013 2014–2017
UAE9006 UAE9007 UAE9013 UAE9015	Focused on enhancing capacity for nuclear and radiological emergency preparedness response & recovery	2007–2009 2009–2012 2016–2018 2019–2021
UAE9012	Focused specifically on enhancing UAE's radioactive waste management	2016–2019

TC activities enhanced the capacity of FANR to oversee the planning, execution, and control of radiation safety at regulatory and implementation levels. Coordination with all relevant national stakeholders facilitated the work of the Radiation Protection Committee in the State.

From 2009 to 2019, the UAE received many IAEA missions in the field of radiation safety, and consolidated an action plan as a result of expert analysis and advice. In 2018 alone, 25% of UAE's collaboration with the IAEA focused on nuclear and radiological safety.

The UAE also received three IAEA peer review missions: Integrated Regulatory Review Service (IRRS), Occupational Radiation Protection Appraisals (ORPAS), and Education and Training Appraisal (EduTA). The UAE addressed

their specific recommendations, and continues to implement the IAEA Safety Standards with respect to radiation safety in the medical, industrial, and nuclear fields.

Analytical and Dosimetry Capabilities.

Through national and regional (ARASIA) TC projects the UAE received technical assistance in terms of equipment and HR development to establish a national secondary standards dosimetry laboratory (SSDL) in Abu Dhabi.

TC projects UAE6004, UAE6005 and RAS/6084 supported the UAE to finalize the construction and procurement of equipment for the SSDL at Khalifa University. The projects also enabled joint work with international experts to support HRD and capacity building in the UAE through training courses, workshops, fellowships, scientific visits, experts meetings, and review missions.

The SSDL continued to receive IAEA support through regional projects within ARASIA, beyond the closure of the national projects to ensure sustainability of its operation.

Under ARASIA Project RAS6084, two SSDL staff attended three regional training courses on calibration techniques, quality management system and uncertainties estimation. In September and October 2017, two IAEA expert missions enabled the SSDL to complete commissioning and get a first evaluation of its Quality Management System.

Materials Analysis Capabilities. To meet domestic requests for material analysis, the UAE launched a TC project establishing its first national facility that offers analytical services through non-destructive testing (NDT). This project was done in collaboration with the University of Sharjah and the American University of Sharjah.

Through national and regional (ARASIA) TC projects, the UAE received technical assistance

TC Projects in Materials Analysis Capabilities

Project	Objective	Years
UAE0006	Enhanced and promoted the use of ion beam analysis and complementary nuclear techniques, such as X-ray fluorescence, to study the characteristics of materials related to archaeology	2009–2012
UAE1011	Supported the establishment of the NDT centre and enhanced its analytical capability for environment and archaeological applications	2012–2016
RAS0051	Supported studying air pollution and modification and characterization of advanced materials using ion beam and other related complementary techniques	2012–2013
RAS0072	Fostered cooperation between ARASIA Member States in the study of air pollution using ion beam and other related techniques	2014–2015
RAS0076	Investigated Atmospheric Particulate Matter and Pollution Source Contributors in urban environments	2016–2018
RAS0078	Supported the studying, characterization, source apportionment and long range transport of air pollution within the regional network	2018–2020

in terms of equipment and HR development to establish a state-of-the-art centre for material analysis using non-destructive nuclear techniques.

IAEA TC projects supported the establishment of the centre and enhanced its analytical capability for environmental and archaeological applications.

The laboratory aimed to provide services in the characterization and analysis of materials to meet the needs of national organizations working on archaeological and heritage artifacts, environmental contaminants in air, water or soil, forensic evidence and new industrial materials.

The centre also received IAEA support through regional TC projects within ARASIA – beyond the closure of the national projects – to ensure sustainability of its operation and continue meeting regional demands in aerosol mapping and analysis.

It also continued its involvement in regional projects within Asia and the Pacific on cultural heritage and archaeology.

ACHIEVEMENTS

Nuclear Power. Seventeen TC projects supported the UAE’s nuclear infrastructure and human resource development programmes and channelled IAEA and international support across many areas.

These projects supported the development of national professional development, and education and training programmes, to sustain the UAE nuclear workforce, and the development of a radioactive waste management strategy and policy (*see figure below*).

Radiation Safety infrastructure. Establishing and enhancing the radiation safety infrastructure of a country requires time and close coordination among multiple authorities. The results obtained in the UAE from a few years of intensive work with the IAEA are impressively tangible.

A few achievements worth highlighting include the following:

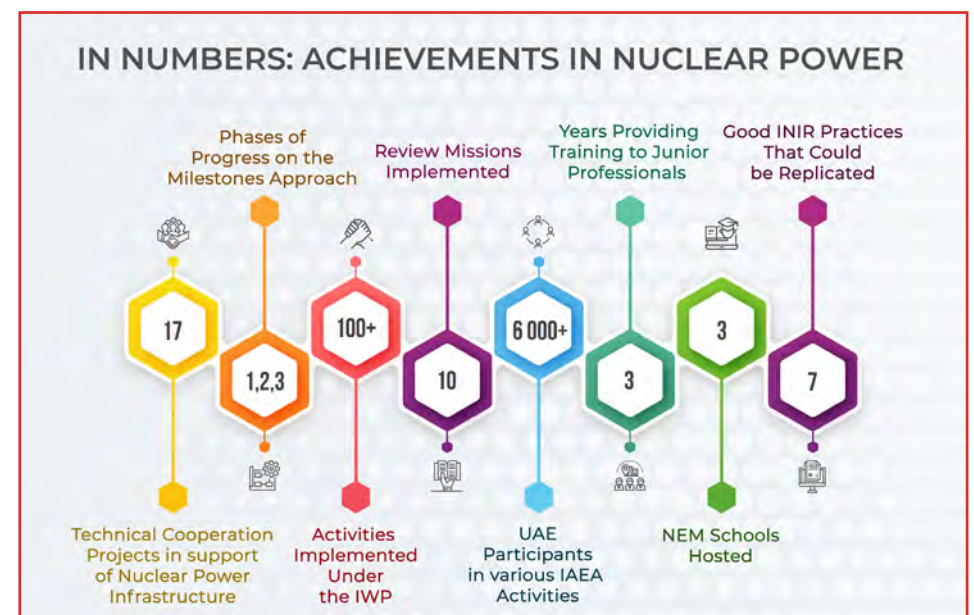
- * Work to develop and implement a national dose register, centralizing exposure data of all radiologically exposed workers in the UAE;
- * Development of a comprehensive system for the safe and secure transportation of radioactive material;
- * Ongoing development of a national framework for health surveillance of occupationally exposed workers;

- * The national framework for calibration of ionizing radiation detection and measurement instrumentation, is ongoing along with the development of corresponding national standards for operational radiation protection;
- * Development of an elaborate and comprehensive system of response, and a Protection Strategy in the event of a nuclear or radiological emergency;
- * Ongoing work towards a coordinated, comprehensive system of response for orphan sources retrieval; and
- * Ongoing efforts to establish a coordinated national network for offline and online measurement, assessment and protection from natural radiation sources in the environment.

Analytical and Dosimetry Capabilities.

The establishment of UAE’s first SSDL at the national level was crucial to meet calibration needs of users in the industrial, medical, research and nuclear power sectors in the country.

With the fast progress of UAE’s nuclear power programme, the SSDL is an important milestone in providing traceability to recognized



measurement standards for ionizing radiation. Such traceability adds confidence in the protection of workers, the public, patients and the environment.

- * The SSDL supports research projects that enhance intellectual and human capital in these sectors. Some achievements include:
- * FANR inaugurated the country's first dosimetry laboratory at the Khalifa University of Science and Technology in Abu Dhabi on April 2018;
- * The UAE SSDL is already a member of the IAEA/WHO SSDL Network and continuously undergoes proficiency tests;
- * In December 2018, the UAE SSDL received the ISO 17025 accreditation, becoming the first accredited SSDL in the Middle East;
- * UAE is now sharing expertise with other countries in this field: In June 2019, one SSDL staff delivered an expert training in Riyadh, Kingdom of Saudi Arabia to train staff there in the maintenance of Quality Management Systems for the SSDLs (SAU6007);
- * The UAE SSDL is in the process of being designated as an ARASIA Regional Resource Center.

Materials Analysis Capabilities. The establishment of the state-of-the-art material analysis centre in the UAE now allows for the provision of a wide range of services – both locally and regionwide – in forensic applications to investigate the authenticities and forgeries of cultural heritage artifacts and paintings; to study air pollution; and to perform applied research in cultural heritage and environmental research (archaeometry).

The centre is already operational and provides additional support for research within the University of Sharjah. It is now a leading national and regional facility, and a hub for

education and training.

The laboratory supported the restoration efforts of the first century temple 'Al-Dor' at Um Al-Quwain, UAE. Analytical techniques, such as Raman and X-ray diffraction, confirmed the nature and composition of the plaster from the temple walls, thus assisting conservationists in the preparation of restoration materials.

Other measurement tools, such as X-ray fluorescence, helped identify the source material of the original mortar used in the temple, by narrowing and matching mortar composition to only one of the five suspected sites.

The centre and its affiliated laboratories now employ three laboratory officers and two full-time research assistants, plus a number of part-time assistants to carry out its work. It collaborates with a number of museums, environmental and industrial agencies, and governmental partners, and is now fully operational.

Some achievements worth highlighting include the following:

- * More than 10 private industrial companies from Abu Dhabi, Dubai and Sharjah regularly use the centre's services for material analysis using advanced analytical equipment;
- * In March 2019, the centre started a long-term collaborative project with the R&D division of Mohammed bin Rashid Solar



IAEA assistance to the UAE was central to the establishment of the SSDL and enhanced national capabilities for dosimetry and calibration (Photo: UAE Permanent Mission to the IAEA).

Park to analyze samples of dust that accumulates on their solar panels. The project also involves investigating the effectiveness of new anti-dust coatings offered by different companies;

- * The centre hosts training sessions for different parties on the use of analytical techniques and equipment for material analysis;
- * Between July and August 2017, the laboratory performed an air quality study for Louvre Abu Dhabi to fulfill the requirements of their higher management before the museum's grand opening in October 2017.

Every year, more than 100 students from different universities around Dubai use the centre's services and facilities for their graduation projects. They include undergraduate and graduate students in science, engineering, and dentistry.

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VIET NAM

TRIANGULAR COOPERATION FOR DEVELOPMENT



ACTIONS TAKEN

In 2017, at the sidelines of the 61st IAEA General Conference, trilateral meetings were held between Viet Nam, IAEA and Lao PDR/ Cambodia to discuss the idea of the triangular cooperation. At these meetings, Lao PDR and Cambodia aired their needs and proposals, while Viet Nam presented its areas of technical competence, and expressed its willingness to support the two countries. The IAEA, in turn, conveyed its cooperation in implementing the proposals.

The parties agreed on the following priority areas for triangular cooperation:

- * State management system on radiation safety;
- * Applications of radiation medicine including nuclear medicine and radiation oncology;
- * Applications of irradiation in mutation breeding;
- * Industrial irradiation; and
- * Non-destructive nuclear techniques.

In June 2018, a trilateral consultative meeting was held to clarify the practical needs of Lao PDR and Cambodia; the technical capacity of Viet Nam in each area; and the development of technical cooperation projects for Lao PDR and Cambodia for the 2018–2019 and 2020–2021 cycles. At that meeting, an action plan for cooperation projects up to the year 2021 was developed.

The roles of each party in the triangular project were also identified as follows:

- * Viet Nam is the country providing technical support/experts;

THE SITUATION

Through the years, Viet Nam has received support from the IAEA in areas such as research and development of nuclear energy applications, and the application of nuclear techniques in industry, agriculture and healthcare, nuclear infrastructure, radiation and nuclear safety. As a result of this support, Viet Nam has developed and enhanced its technical and human capacity in these areas, and marked some remarkable achievements.

From 2013–2015, Viet Nam implemented a bilateral project which helped Lao People's Democratic Republic (Lao PDR) improve its legal infrastructure and enhance its technical capacity in radiation safety. The outcomes of this project were highly appreciated by Lao PDR, which expressed its desire for continued Vietnamese support in these areas in the years to come.

Cambodia, meanwhile, was just entering the field of atomic energy. Cambodia's activities in nuclear energy application were still limited. It did not yet have a legal document system on radiation safety. It had very limited personnel in these fields; and did not give adequate attention to radiation safety issues. Viet Nam, therefore felt that it needed to share its experience and support with Cambodia in developing nuclear energy application and radiation safety.

Viet Nam first raised the idea of a technical cooperation project supporting its neighbouring countries in August 2017 at the 12th Vietnam Conference on Nuclear Science and Technology held in Nha Trang. In its proposal, Viet Nam indicated that a triangular technical cooperation project supporting Lao PDR and Cambodia would be an important step to promote the spirit of South-South cooperation.

- * IAEA is the coordination body providing financial support for activities under TC projects;
- * Lao PDR and Cambodia are the countries receiving technical support. Technical cooperation activities will take the form of missions of Viet Nam experts to Lao PDR and Cambodia, and scientific visits and fellowships of Lao and Cambodian officers to Viet Nam.



in medicine and in ISO/IEC/17025 in NDT. Through this project, Lao PDR will strengthen its capacity in applications of nuclear techniques that contribute to economic development.

In the field of mutation breeding, Laos officers were trained on mutation induction, development of M2 mutant population, mutation detection and selection criteria and establishment of mutant lines. Viet Nam's Ministry

of Agriculture also supported Lao PDR in the field of water resources management and in rice and corn production.

One of the early constraints was to identify the financial responsibility of each party in implementing the activities. It was agreed that the activities under ongoing TC projects for Lao PDR and Cambodia will use funding from these projects. For other activities, the three countries will decide how to best share the financial responsibilities according to agreed levels.

With strong support from the respective governments and the IAEA, the following activities were implemented:

- * In October 2018, Viet Nam approved a project supporting the Lao PDR Ministry of Science and Technology to build a center for non-destructive testing (NDT). The project would be implemented from November 2018 to November 2020.
- * From March to May 2019, with funding from IAEA TC project LAO5004, Viet Nam received three Lao PDR officers for training on mutation induction.
- * From 6-10 August 2018 in Hanoi, a Cambodian delegation from the Ministry of Mines and Energy headed by Deputy Minister Tun Lean visited Viet Nam. They

met with Vietnamese Deputy Minister Pham Cong Tac and worked with relevant agencies. The two sides expressed support and willingness to carry out the cooperation activities as planned.

While Viet Nam developed the activities for the triangular project, final implementation needed the continuous support of governments and the IAEA, particularly with regards to funding.

ACHIEVEMENTS

Although still ongoing, the triangular cooperation projects already have made outstanding progress and gained positive achievements, in spite of certain difficulties.

Lao PDR-IAEA-Viet Nam

For Lao PDR, a number of officers from DSM/MOST were trained on NDT methods under the project funded by Viet Nam. The trainees were provided with basic knowledge on NDT and practical experience on NDT methods used in Viet Nam. They were also trained on radiation safety, inspecting X-ray machines

of Agriculture also supported Lao PDR in the field of water resources management and in rice and corn production.

From 25–29 March 2019, Viet Nam also helped Lao PDR to develop an IAEA TC project on NDT.

Cambodia-IAEA-Viet Nam

For Cambodia, Viet Nam helped to enhance capacity for technical officers on personal dosimetry and radiation safety techniques. Specifically, four Cambodian officers were trained on basic radioactive chemistry techniques. Viet Nam also helped to set up a laboratory on basic radioactive chemistry techniques. It also helped set up a laboratory in Da Lat on individual dosing and trained two Cambodian officers on individual dosing techniques, and in the use of different types of dosimeters.

In March 2019, Viet Nam also helped Cambodia to develop a project on insect/fruitfly sterilization (KAM5005).

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YEMEN

ENSURING FOOD SECURITY WITH NUCLEAR TECHNIQUES

| THE SITUATION

Agriculture is a major source of employment and an increasingly important sector in Yemen's economy. The objective of the agricultural sector is to promote and increase the sustainable production of food. However, the country's efforts have been hampered by salinity, drought, pest and disease, which are the major constraints to sustainable agricultural production in Yemen.

To address this issue, Yemen's national programme has put emphasis on the need to develop new varieties of crops, like wheat and barley, that mature quickly, are drought tolerant and disease resistant.

| ACTIONS TAKEN

Nuclear and isotopic techniques, in particular, have shown promising results in developing improved crop varieties with desirable agronomic traits, including drought tolerance. Such crops could help manage and save agriculture water, particularly in areas where water is limited.

Hence, by applying nuclear techniques within the framework of the IAEA technical cooperation programme, different mutant varieties of wheat and barley crops have been developed.

As farmers adopt and start planting these new crop varieties, food production will undoubtedly increase, as well as the income of farmers.

| ACHIEVEMENTS

From 2007 onwards, there has been continuous collaboration between the IAEA and Yemen's Agricultural Research and Extension Authority (AREA). National and regional projects have been implemented to enhance the productivity of wheat and barley crops with the aim of increasing grain production and farmers' income.

Within the framework of these technical cooperation projects, three wheat mutant varieties have been officially released. These are Bouth 1, improved Arabi-1 and improved Sonalika. These new varieties are characterized by early maturity, resistance to lodging and disease – specially rust disease – with high yielding potential.

The improved Bouth-1 variety has been adopted by farmers in Amran area. Since its introduction in this area, wheat production is widely expected to improve. The mutant variety Arab-1 is resistant to lodging and is adapted to rainfed areas. The improved Sonalika variety, meanwhile, is resistant to yellow rust and is much more suited to areas infected by rust disease.

In addition to that, two mutant varieties of wheat, namely Erra-008-Gw-45-40 and Erra-008-Gw-46-54, were tested in the Shibam and Amran regions. A technical report is being prepared for submission to a special committee before their release.

The TC projects have also succeeded in developing two mutant varieties of barley, namely Al-erra-B-008-84-13 and Al-erra-B-008-85-15. These mutants are characterized by early maturity, resistance to lodging and improved yields. They have been adopted by farmers in rainfed areas of the highlands of Yemen, especially in the regions of Shibam Kawkaban, Bani-Mater and Khulan Affar.

In future, steps will be taken to disseminate the seeds to more farmers in rainfed sectors and to register them as improved mutant varieties.

Additionally, two improved wheat varieties which are tolerant to drought have been developed using carbon isotopic discrimination (CID) technique. It is planned to officially release them for cultivation in the near term.

Encouraging results were also obtained in water and nitrogen fertilizer management on potato and cabbage crops. The use of nuclear techniques resulted in savings of up to 50% in water irrigation while using only half the amount of nitrogen fertilizer. Farmers also recorded a slight increase in yield compared to traditional agricultural practices.

Capacity building

Capacity building has been an important component of the TC projects and training was provided for project counterparts in the area of advanced mutation breeding and *in vitro* techniques.



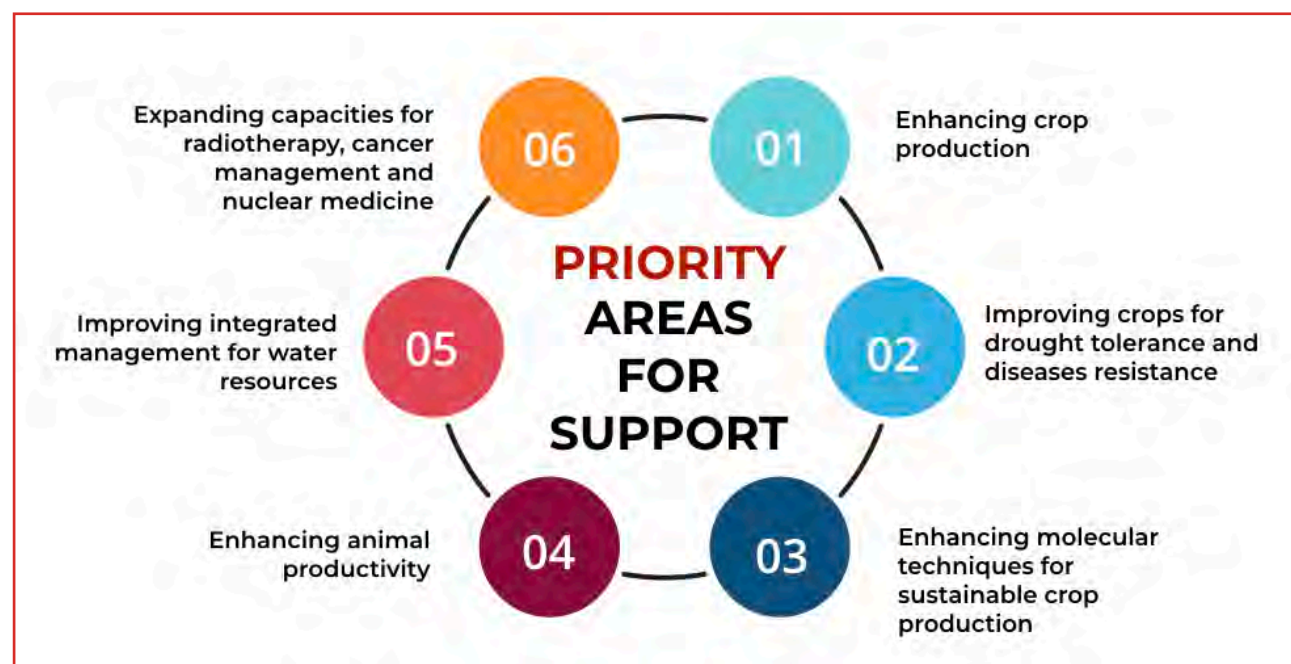
The planting of improved mutant varieties of wheat can increase food production in Yemen, as well as the income of farmers (Photo: NAEC).

Other training areas included: screening techniques for drought tolerance and disease resistance; management of different mutagenized populations in self-propagated crops; identification and documentation of mutant; doubled haploid (DH) methods for crop improvement; and mutant phenotyping.

Training was delivered through workshops, fellowship training, group training, meetings, and scientific visits. Upon completion, all project counterparts had become familiar with the techniques and succeeded in selecting mutants of targeted crops carrying desired characteristics.

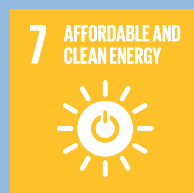
An expert mission was also undertaken to assist staff in other countries like Oman, Qatar and Saudi Arabia to establish mutation breeding programmes, organize staff lectures; formulate teams; and design plans for future work.

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The staff of the IAEA Division of Technical Cooperation for Asia and the Pacific (TCAP) joins the journey to success of all Member States and territories from the Asia and Pacific region.





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