PUI STORIES

2017 Edition

IAEA

60 Years

Atoms for Peace and Development

IAEA

What is the Peaceful Uses Initiative (PUI)?

The Peaceful Uses Initiative (PUI), launched in 2010, has become instrumental in mobilizing extra-budgetary contributions which supplement the Technical Cooperation Fund to support technical cooperation footnote-a projects and other unfunded projects of the IAEA in the peaceful application of nuclear technology.

Extra-budgetary contributions made through PUI have been used to support a wide variety of IAEA activities aimed at promoting broad development goals in Member States, such as in food security, water resource management, human health, nuclear power infrastructure development and nuclear safety, many of which would have remained unfunded without PUI.

PUI has also allowed the IAEA to be more flexible and quicker in responding to evolving priorities of Member States, as well as to unexpected needs or unforeseen emergency events, as demonstrated in the response to the Ebola virus disease in West African States and the outbreak of the Zika disease in Latin America and the Caribbean. To date, PUI has helped mobilize over €100 million in financial contributions from 21 Member States and the European Commission, in support of more than 200 projects that benefit over 150 Member States. The IAEA will continue its work on PUI to further promote the benefits of the peaceful uses of nuclear science and technology, contributing to "Atoms for Peace and Development" and the attainment of the Sustainable Development Goals.

To make an extra-budgetary contribution through PUI:

- Member States initiate the process by sending a pledge letter to the IAEA. These letters should be addressed to the Director General and should include the following information:
  - the name and contact details of the Member State making the contribution;
  - the amount of the contribution and the specific project to fund; and
  - indicate in the pledge letter that the contribution is made through PUI.
- The IAEA will initiate the formal acceptance process for the contribution and respond to the initial pledge letter.

Member States that are considering a contribution through PUI are encouraged to closely consult with the Secretariat prior to making an official pledge.

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ATOMS FOR PEACE AND DEVELOPMENT:
contributing to global progress through nuclear science and technology

The IAEA plays an important role in tackling both emerging and longer term global challenges through the peaceful application of nuclear technology. Generating energy, tackling climate change, making the benefits of modern health available to all and helping countries respond to emergencies such as the Ebola and Zika viruses are just some of the areas in which the IAEA assists its Member States.

The Peaceful Uses Initiative (PUI) has been instrumental in supporting a wide variety of IAEA activities aimed at helping Member States achieve their development objectives. Assisting countries in the peaceful application of nuclear technology for development is as important to the IAEA as its non-proliferation work. For many developing countries, it is the most important thing we do.

I very much welcome the fact that science and technology are explicitly recognised as important contributors to the post-2015 development agenda in the Sustainable Development Goals adopted in 2015.

Nuclear science and technology, in particular, have much to contribute to sustainable development. The IAEA has assisted countries in developing new food crops that are resistant to drought, enabled them to use nuclear testing methods in industry and helped them use nuclear techniques to manage limited water resources. Nuclear power can make an important contribution to reducing carbon dioxide emissions as countries work to meet their commitments under the Paris Agreement on climate change.

One of the most gratifying aspects of my work as IAEA Director General is meeting people whose lives have been changed for the better by our work. In this brochure, we illustrate the impact of the IAEA's work through eight examples, financed through the Peaceful Uses Initiative, which span a broad range of our activities.

The IAEA continues to celebrate its 60th anniversary in 2017 with the official motto "Atoms for Peace and Development". Membership of the IAEA continues to grow and demand for our services in all areas of nuclear sciences and applications is increasing steadily. PUI has been an effective mechanism in mobilizing additional resources to meet this growing demand. We will continue to put these resources to work for the benefit of Atoms for Peace and Development in the coming years.

— Yukiya Amano,
Director General, IAEA

(Photo: L. Gil/IAEA)

Vets in Africa help prevent spread of Ebola and other zoonotic diseases

An animal as tiny as a bat can carry up to 137 different virus species. Many of these, including Ebola, can be transmitted to humans. After years of studying bats and other animals in the jungles of central Africa, scientists are joining forces under IAEA projects to prevent the spread of diseases that can be transmitted from animals to humans, known as zoonotic diseases.

"Around 75% of human diseases originate from animals, which is why it is so important to stop them at the animal level," said Abel Wade, Director of the National Veterinary Laboratory in Yaoundé, Cameroon. "Nuclear-derived technology helps us do this."

During the Ebola epidemic of 2014, the IAEA quickly reacted to provide specialized diagnostic equipment to help Sierra Leone in its efforts to combat the virus. With the immediate crisis over, the focus now is on longer term prevention. The IAEA, in cooperation with the Food and Agriculture Organization of the United Nations (FAO) and through funding from the Peaceful Uses Initiative (PUI) and from the African Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology (AFRA), is helping countries use nuclear-derived techniques to detect zoonotic diseases and respond to them.

Polymerase chain reaction (PCR) technology allows the identification of viruses such as Ebola within a few hours and with a high degree of accuracy (see The Science box, page 5). Early diagnosis helps curtail the spread of diseases by

"Around 75% of human diseases originate from animals, which is why it is so important to stop them at the animal level. Nuclear-derived technology helps us do this."

Abel Wade, Director, National Veterinary Laboratory (LANAVET), Yaoundé, Cameroon

making it possible to rapidly isolate and treat infected animals and patients earlier. To African countries facing the threat of new outbreaks, the IAEA's help in equipping their laboratories and training their scientists in the use of these techniques and the corresponding biosafety measures has been critical.

"With this technology we're better prepared to respond at the first sign of a disease," said Emmanuel Nakouné, Scientific Director at the Institut Pasteur in Bangui, Central African Republic. "But if one country's surveillance is weak, it can put the whole region in danger. That's why we're working together to strengthen surveillance throughout the region."

Regional cooperation

In 1999, Nakouné spent three weeks in the jungle in south-west Central African Republic living with the local people until he found a potential source of the Ebola virus: rodents. Back in his lab, he used the PCR technique to discover that these were the animals that were transmitting the virus to humans in that area.

Early March he hosted Wade for a week of information exchange and joint work.

"The ongoing information exchange between various disciplines and different countries is an exemplary case of knowledge transfer under the United Nations-supported One Health approach," said Michel Warnau, who is in charge of the technical cooperation project on Emerging Zoonotic Diseases at the IAEA. "For example, Wade is learning how doctors in Bangui spotted Ebola in the early 2000s and a monkey pox outbreak more recently using nuclear-derived techniques. Vice versa, Wade is sharing his expertise and experience in stopping the spread of a dangerous zoonotic disease that affected Cameroon."

Controlling the 2016 bird flu

In mid-2016, a farm complex near Yaoundé lost 15,000 chickens. Veterinary scientists from LANAVET — Cameroon's National Veterinary Laboratory — collected samples of the dead chickens and took them to their laboratory in Yaoundé, which was almost completely furnished through the IAEA's Peaceful Uses Initiative. The vets used nuclear-derived techniques, such as PCR and ELISA, to discover that they were witnessing an outbreak of H5N1 avian influenza, a dangerous disease that can also be transmitted to humans.

"As soon as we detected it, we informed all the relevant ministries, the army, everyone," Wade said during a presentation to researchers at the University of Bangui. After imposing all necessary sanitary measures, killing all infected animals, disinfecting all affected farms and halting chicken trade, Cameroonians managed to stop the outbreak.

It was a success, but at a significant cost to the country, Wade said. At the peak of the outbreak, farmers in western Cameroon were losing FCFA 6 billion (EUR 9 million) every day. Animal diseases can present devastating

(Photo: L. Gil/IAEA)

consequences to farmers, families and communities. Once they identify the animal disease in the lab, veterinarians can provide farmers with drugs or vaccines, but in some cases — like avian influenza — killing the flock is the only way to stop the spread.

Wade's message to researchers at the University of Bangui was clear: "Nuclear-derived diagnostic techniques allow us to detect the virus early but once you've identified the disease, you need to act. Farmers might suffer economic losses, but saving one human life is priceless."

Guimdo Tshicitoing Guy Flaubert, owner of a chicken farm on the outskirts of Yaoundé, was still losing animals seven months after the outbreak when he called the LANAVET scientists for help. After they used PCR and ELISA to discover that his chickens were not dying due to avian influenza, Guy Flaubert could sleep again. "I could've tried everything but I would've never got to the real cause of the problem by myself. There are things only these machines can see," he said.

Thanks to the precision that LANAVET's molecular diagnostics laboratory offered during the avian influenza crisis, more and more farmers are reaching out for help. In 2016 alone, 230 farmers took dead or sick animals to LANAVET in Yaoundé for examination.

In Bangui, Wade learnt how PCR can be used to identify a relatively new disease spotted in the jungles of the Democratic Republic of the Congo (DRC): monkey pox, a virus of rodents and primates that also causes smallpox-like symptoms in humans. In recent years, monkey pox has re-emerged in several countries, including the Central African Republic.

At his next stop in Ndjamena, Chad, Wade learnt about his peers' experience in using nuclear-derived techniques to identify rabies and tuberculosis and endeavoured to establish the collaboration so crucial for the surveillance and control of Ebola and other animal diseases that can be transmitted to humans.

In sub-Saharan Africa, the majority of pathogens are still unknown, Wade said, emphasizing the need to collaborate. "In the world, a new disease appears or an old one re-emerges every four months. We cannot control this if we work alone. We need to share our expertise in using these powerful, life-saving techniques. Remember that a life saved in the Central African Republic means many lives saved in Africa."

(Photo: L. Gil/IAEA)

THE SCIENCE

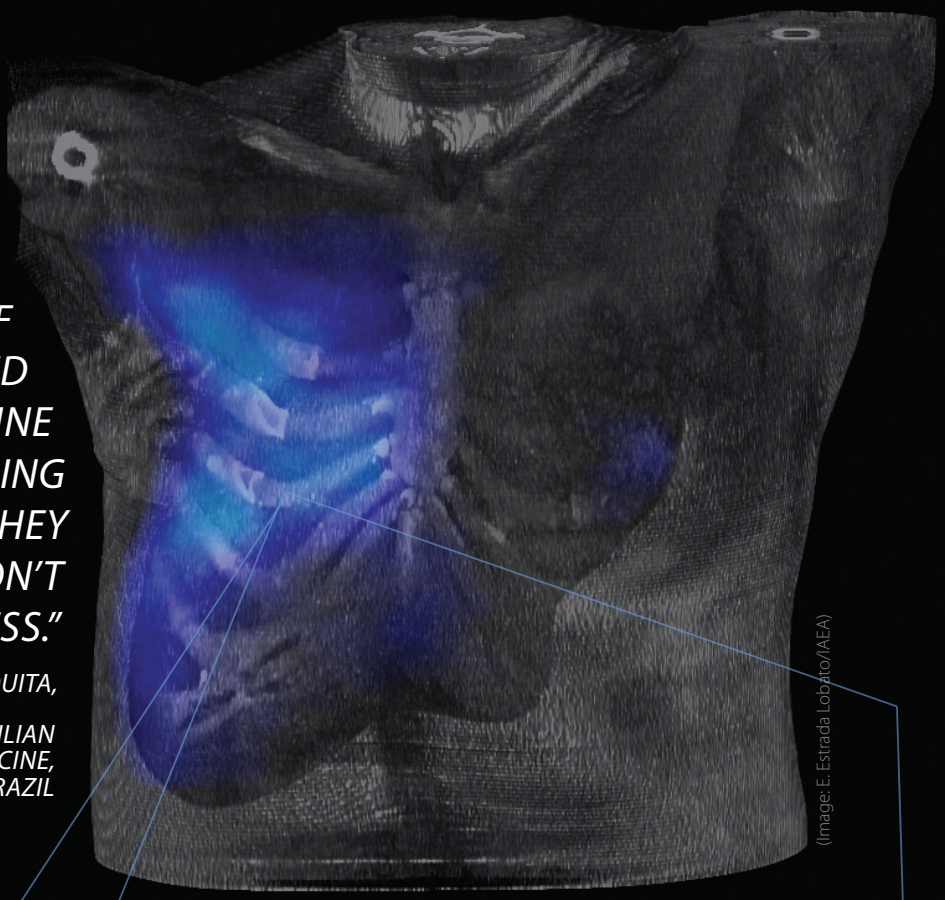
Nuclear-derived techniques for detecting animal diseases

The enzyme-linked immunosorbent assay (ELISA) and the polymerase chain reaction (PCR) are two nuclear-derived techniques commonly used for disease diagnosis.

ELISA is easy to setup and use, which makes it suitable for any veterinary laboratory. Scientists place a diluted serum sample from an animal on a prepared dish and if the sample contains the suspected disease, it causes an enzyme in the fluid to change the liquid's colours confirming the presence of the disease. ELISA is often used for initial tests, but it has a limited sensitivity and specificity and cannot be used to identify virus strains.

PCR is a technique involving more sophisticated equipment and procedures than ELISA, and is highly sensitive and accurate, making it well-suited for identifying virus strains and bacteria. This technique uses an enzyme to replicate, or amplify, a specific genetic region of a pathogen's DNA billion-fold in just half an hour. Scientists then detect and monitor this DNA amplification through either radioisotopes or by counting fluorescent molecules attached specifically to the created gene sequences.

Both methods originally worked with radioisotopes and now apply enzymes instead, which has helped the IAEA and its partners to refine and streamline the testing process.



(Image: E. Estrada Lobato/IAEA)

"THE NUMBER OF PATIENTS THAT NEED NUCLEAR MEDICINE EXAMS IS INCREASING EVERY YEAR, BUT THEY OFTEN DON'T HAVE ACCESS."

CLAUDIO TINOCO, MESQUITA,

PRESIDENT OF THE BRAZILIAN SOCIETY OF NUCLEAR MEDICINE, BRAZIL

Harnessing atoms to save hearts and fight cancer

Nuclear medicine in Latin America and the Caribbean

Over 600 million hearts are beating in Latin America and the Caribbean, pumping life into bodies that are living longer, but often leading more sedentary and unhealthy lifestyles. The continent's growing and aging population relies in part on access to nuclear medicine services that improve cost-effective management of the main causes of death: cardiovascular diseases and cancer.

"The number of patients that need nuclear medicine exams is increasing every year, but they often don't have access," said Claudio Tinoco Mesquita, President of the Brazilian Society of Nuclear Medicine. "In my country, for example, there should be at least double the number of nuclear medicine centres to cover the growing population's needs, from departments, equipment and trained

"Early and accurate diagnosis is critical for effective treatment of both cardiovascular diseases and cancer."

Diana Paez, Head, Nuclear Medicine and Diagnostic Imaging Section, IAEA

professionals, of everything. We are working very hard to improve access to nuclear medicine services. For that, the support of the IAEA has been essential."

Cardiovascular diseases (CVDs) kill more people than any other health condition in the world, closely followed by cancer. In Latin America and the Caribbean, about half of all deaths are due to CVDs and cancer, especially of the lungs, prostate, breast and cervix.

Nuclear medicine is a small, but key area of health care (see The Science box, page 9) that uses atoms that emit radiation, known as radionuclides, to diagnose, treat and manage diseases and health conditions. This field relies on specialized drugs called radiopharmaceuticals, sophisticated tools such as cyclotrons and diagnostic imaging devices such as positron emission tomography (PET) and single photon-emission computed tomography (SPECT) and highly specialized medical professionals.

"Early and accurate diagnosis is critical for effective treatment of both cardiovascular diseases and cancer," said Diana Paez, Head of the Nuclear Medicine and Diagnostic Imaging Section at the IAEA. "Nuclear medicine provides essential diagnostic and therapeutic services that help doctors care for cardiac and cancer patients, and when diagnosed early, treatment can begin sooner, leading to improved patient outcomes."

Access to nuclear medicine in Latin America and the Caribbean is often uneven and limited, particularly in rural areas, Paez said. "While private health care often offers more nuclear medicine services, many public facilities lag behind, and these are the hospitals most people rely on."

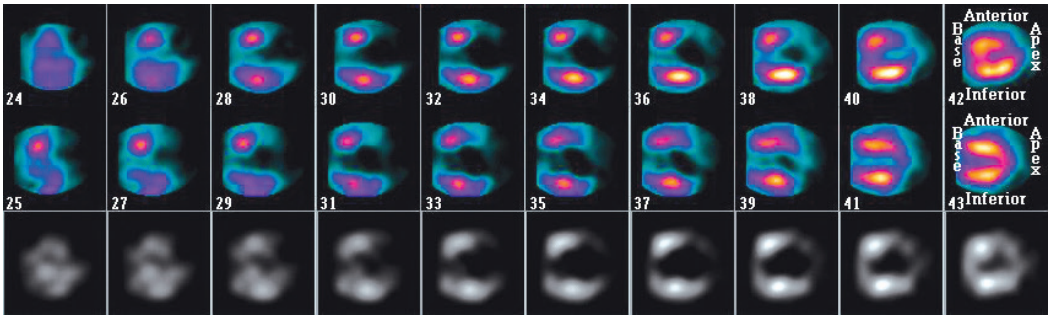
Providing equipment, offering training

To help bridge gaps in health care, the IAEA, through its Technical Cooperation Programme and with the support of the Peaceful Uses Initiative (PUI), has played a key role in facilitating the development and improvement of nuclear medicine on a national level and across the region. This includes providing support for purchasing equipment, and, as of 2016, face-to-face training for more than 600 professionals in specialized skills and carrying out more than 500 expert missions to raise awareness among health care practitioners and decision makers of the clinical applications of nuclear medicine.

(Photo: E. Estrada Lobato/IAEA)

Through online training courses in nuclear medicine diagnostics, more than 1200 professionals have been trained in the region. In addition, over 1000 specialists have also participated in webinars, conferences, and other continuing education activities and post-graduate work supported, and in many cases sponsored, by the IAEA. The IAEA also supports research and development through, among others, partnerships with national and regional nuclear medicine institutes, as well as technical meetings and international conferences. The IAEA works with its Member States in part through the Regional Technical Cooperation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean Region.

"Assisting countries to improve their nuclear medicine services and to transfer innovative technologies to benefit patients is an important aspect of our development efforts in the region," said Luis Carlos Longoria Gandara, Director of the IAEA's Division for Latin America and the Caribbean. "Access to quality health care services like these can help prevent unnecessary deaths and improve people's lives."



(Image: E. Estrada Lobato/IAEA)

THE SCIENCE

What is nuclear medicine?

Nuclear medicine techniques evaluate the function of any organ or structure in the body. They provide unique information and offer the potential to identify diseases in early stages.

The majority of nuclear medicine procedures take place inside the body through specialized drugs called radiopharmaceuticals, which contain radionuclides — atoms that emit radiation — produced in nuclear research reactors or cyclotrons, a type of machine that accelerates charged particles in a vacuum. When these drugs are taken into the body, the radionuclides interact with certain tissues or organs due to their specific chemical properties without disturbing or damaging them. A special detector, such as a gamma camera, outside the body can detect the small amounts of radiation emitted from the organ or tissue. The camera is then able to translate the information into images of the specific tissue or organ.

Among the more well-known and the fastest growing of these techniques is positron emission tomography (PET). PET scans are often combined with other scanning techniques such as computed tomography (CT) to further enhance the speed, accuracy and usefulness of nuclear medical imaging.

Nuclear medicine is also used for treatment of some diseases and health conditions, such as thyroid cancer or relieving or lessening bone pain related to metastases. Doctors choose small quantities of radiopharmaceuticals that certain body parts absorb more significantly and more effectively than other body parts. This allows them to target specific areas during treatment. The small amounts of radiation in the radiopharmaceuticals then kills off the cells causing the health condition, with minimal effect on other cells in the surrounding area and the rest of the body. The combination of the diagnostic and therapeutic applications of nuclear medicine is increasingly growing. It allows the identification of specific tumour cells, and therapy can be tailored to fit the needs of individual patients.

How nuclear technology helps women farmers in Sudan move out of poverty

In eastern Sudan under the blistering sun, women covered colourfully head-to-toe chatter away as they harvest lush green vegetables to feed their families, their neighbours and their wallets. Their fields thrive among long stretches of parched earth because nuclear science has helped them to make the most of limited water supplies and optimize fertilizer use.

"We used to have nothing. We had little food, and we had to buy it at the market. We did not even know how vegetables were grown," said Fatima Ismail, a farmer from a small village outside of Kassala where an IAEA-supported drip irrigation project has been ongoing since 2015. "We now know how to deal with the soil and how to grow our own food. We are very eager to expand and to have all of our neighbours and other women in the village use this method, too."

These hundreds of women have been living constrained lives with few opportunities for change. They and their families, many of whom are refugees or internally displaced, had limited food resources and relied on their husbands' meagre income. While their husbands are allowed to work, the women did not have an option to grow their own food or leave their homes to work and earn a living. Due to the cost of buying food, sometimes at prohibitive prices, particularly during the off season, many people in these villages are malnourished.

"If the women are empowered, they can share in the decision-making in the family and the community. It helps to reduce poverty, and it makes future planning more effective. When women are empowered, the community is more empowered."

Rashid Sir El Khatim, Coordinator, Talawiet Organization for Development, Sudan

Now, through small-scale farms and home gardens optimized using nuclear science and technology, the women, their families and entire villages benefit from access to all sorts of vegetables, from onions and eggplants to okra and leafy greens.

Agriculture is the primary source of income and livelihood for up to 80% of the population in Sudan.

"Before this, my child suffered from malnutrition, and I had to take him to the doctor very often," said Haleema Ali Farage, another woman farmer participating in the project. "Now with more food and more nutrition from the vegetables, he has not gone to the doctor for months."

Science was the starting point of a new change for these women. Thanks to a project funded in part through the Peaceful Uses Initiative (PUI), local scientists from the Agricultural Research Cooperation (ARC) were trained and provided technical support by experts from the IAEA, in partnership with the Food and Agriculture Organization of the United Nations (FAO). The scientists learned to use the soil moisture neutron probe technique to measure and determine moisture levels in their soil at Kassala Research Farm; to quantify the amount of water needed by the crops; and to use the nitrogen-15 isotopic technique (^{15}N) to optimize nitrogen fertilizer applications (see The Science box, page 13). These scientific studies then formed the basis to determine how much water and fertilizer to deliver through the watering system known as drip irrigation.

"Studying the atoms in soil, water, fertilizer and crops is a very precise way to determine what works and what doesn't. It helps us strike that fine balance between protecting

(Photo: N. Jawerth/IAEA)


(Photo: N. Jawerth/IAEA)

soil and saving as much water as possible while still allowing crops to flourish," said Lee Heng, Head of the Soil and Water Management and Crop Nutrition section of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

Every drop counts

The low cost drip irrigation system is easy to install and simple to use: it involves a giant raised tub of water that is controlled by an on-off valve, which, when switched on, uses gravity to draw the water mixed with fertilizer down into a series of tubes placed directly at the base of the plants. Using this method of combining water and fertilizer through drip irrigation is called 'fertigation'.

"Although not a new technology in itself, it is only when set up correctly and optimized using scientific data that drip irrigation can be effective with very little water waste," said Heng. This system and fertigation method is promoted by the FAO for countries and regions where water is scarce and at a premium.

"What makes this drip irrigation system new and innovative is what has been released from ARC," said Rashid Sir El Khatim, Coordinator from the Talawiet Organization for Development. The ARC provides local NGOs like Talawiet with a complete package for setting up and using drip irrigation and fertilizer, optimized through the scientific work done with IAEA support. "If you compare this drip irrigation system to other systems, there is a big difference. It can save water by up to 70%, which means there is enough water for more farming."

Pilot studies were conducted in fields around Kassala state, along the border with Eritrea. This area is often called the 'bread basket' of Sudan as the soil is rich with nutrients, and when combined with adequate water, has shown to be an excellent environment for growing food. However, water supplies increasingly run short due to rising temperatures and climate change.

"Water, soil, temperature: it's all a complete package," said El Saddig Suliman Mohamed, ARC's Director General. "Without a proper irrigation system, you can't maximize yields, but on the other side, without using fertilizer right you can't reach the soil's full potential. Every component without the others is nothing. So we have to look at the whole package."

Once the scientists determined the optimal amount of water and fertilizer needed for the crops to thrive, they helped set up the drip irrigation system and trained farmers to use it and to properly apply fertilizer. The training was distilled down to easy-to-follow instructions that reflected the scientific findings. This has allowed the farmers to benefit from the science while taking ownership of the process, from cultivating the fields to monitoring their crops and marketing their produce.

The success of the IAEA pilot project in reducing water use by up to 70% while increasing food yields by more than 40% drew the attention of other organizations throughout Kassala, such as the Sudanese Red Crescent (SRC) and Talawiet. With funding from the office of

the United Nations High Commissioner for Refugees (UNHCR), FAO and the World Food Programme, among others, the Red Crescent and Talawiet have worked closely with IAEA-trained scientists from the ARC to set up and run more than 85 small-scale farms and home gardens for over 1050 women. Following the success of these projects, the ARC, Talawiet and the Red Crescent are now working to establish 15 drip irrigation systems for over 450 women in north and south Kassala State and Red Sea state. They are also working to expand into the neighbouring region of Butana.

Women's empowerment for sustainable change

While the whole village benefits from these agricultural projects, women have been the primary focus because of the important role they play in family well-being. Women in developing countries invest much more of their earnings in their children's education and health than men do: 90% of their income compared to 30-40% by men. This trend has the potential to break intergenerational cycles of poverty, according to the World Bank.

The women involved in these projects are generally selected based on key criteria that take into consideration their ability to participate as well as their level of need. The NGOs, through support from international organizations, have launched these small-scale agriculture programmes with wider initiatives involving, among others, educational courses, microfinance opportunities and business guidance.

"If the women are empowered, they can share in the decision-making in the family and the community," said Sir El Kahtim. "It helps to reduce poverty, and it makes future planning more effective. When women are empowered, the community is more empowered."

The drip irrigation system has also been identified by the United Nations Framework Convention for Climate Change (UNFCCC) as effective for sustainable climate change adaptation and mitigation. It is now labelled as a UNFCCC National Adaptation Programme of Action model for use worldwide.

The women, in the meantime, are eager to continue building on their success.

"We want to do more," said Ismail. "We want to expand the area and grow more and new types of vegetables. We want to help educate others to do this. We need another water tank, so all of our neighbours and all the women in the village get involved. We want everyone to have a chance. We are ready."

THE SCIENCE

Soil moisture neutron probe and nitrogen tracking

The scientists use a soil moisture neutron probe to monitor moisture levels in soil at a selected research farm. During measurements, the probe emits neutrons that collide with the hydrogen atoms of water in the soil. The collision slows down the neutrons. The change in neutron speed is detected by the probe and provides a reading that corresponds to the moisture level in the soil. The higher the number of hydrogen atoms, the more neutrons are slowed down, and, when measured, indicates a higher level of moisture.

Nitrogen is a key component of soil and fertilizers that plays an important role in plant growth and photosynthesis, the process through which plants convert energy from sunlight into chemical energy. As nitrogen atoms interact with the atoms in soil, fertilizer, and water, they change into forms taken up by plants, released in the air, or absorbed further into the ground. Using fertilizers labelled with nitrogen-15 (^{15}N) stable isotopes — atoms with extra or missing neutrons — scientists can track the isotopes to determine how effectively the crops are responding to and taking up the fertilizer. This method is called the nitrogen-15 isotopic technique, and by using this approach, management practices can be improved, which in turn can help increase crop yield and optimize fertilizer use.

"Nuclear techniques will be indispensable in eradication efforts through the use of isotopic techniques in vaccine development and to monitor the spread of PPR."

Berhe Tekola, Director, Animal Production and Health Division, FAO

(Photo: IAEA)

Tackling transboundary animal diseases

How nuclear science is making a difference

Fast and accurate diagnosis and monitoring of animal diseases can make the difference between living in poverty and having a steady source of food and income. In countries where livestock play a key role in everyday life and development, a network of laboratories called 'VETLAB' offer scientists an avenue for diagnosing and monitoring diseases using nuclear and nuclear-derived techniques to help ensure a stable future for farmers. The network is financed through the Peaceful Uses Initiative (PUI) and the African Renaissance Fund.

"The farmer is the one who benefits. The more diseases we control, the more animals the farmers have. And if they have more animals, poverty is reduced," said Christopher Simuntala, Head of the Central Veterinary Research Institute in Lusaka, Zambia, who learned how to use these nuclear and nuclear-derived techniques at a training course held by the IAEA in partnership with the Food and Agriculture Organization of the United Nations (FAO).

"The farmer is the one who benefits. The more diseases we control, the more animals the farmers have. And if they have more animals, poverty is reduced."

Christopher Simuntala, Head, Central Veterinary Research Institute, Zambia

One billion people, mostly pastoralists in South Asia and sub-Saharan Africa, depend on livestock for food and livelihood, according to the FAO. Many animal diseases are highly contagious and can spread extremely quickly within a country and across borders, hindering trade and, in some cases, affecting public health.

"Molecular diagnosis helps us understand the spread of diseases," Simuntala said. "We are able to tell whether a disease originated in our area, or started elsewhere and then moved to our country, and also which animals are carrying the diseases. This will help us in predicting threats and controlling disease."

Nuclear-based technologies can be used to detect viruses like capripox disease, peste des petits ruminants (PPR), African swine fever, foot and mouth disease, Newcastle disease, and highly pathogenic avian influenza in a single pathogen or a multi-pathogen detection system.

"Conventional methods used in many developing countries can detect the viruses, but this takes a long time and cannot determine its behaviour or character," said Charles Euloge Lamien, specialist in animal health at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. "And viruses change. With the use of full genetic sequencing, the detection method is more refined and sophisticated." (See The Science box, page 17.)

Going after PPR

One of the most damaging livestock diseases in Africa, the Middle East and Asia is the highly contagious and widely spread PPR virus. It kills thousands of sheep and goats per year and causes annual economic losses estimated at over US $1.4 billion. First reported in 1942, PPR has since spread to over 70 countries and 50 others are considered at risk, according to the FAO and the World Organisation for Animal Health (OIE).

A global effort is now underway to eradicate PRR by 2030 using nuclear and other techniques, and the 'VETLAB' network of animal health laboratories will play a critical role in this effort. The Global Control and Eradication Strategy is fashioned after the successful global eradication programme for rinderpest, a virus closely related to PPR, which was declared eradicated in 2011 with the help of nuclear techniques and the VETLAB network.

"One of the major constraints faced by those involved in the livestock sector is PPR," said Berhe Tekola, Director of the FAO Animal Production and Health Division. "Nuclear techniques will be indispensable in eradication efforts through the use of isotopic techniques in vaccine development and to monitor the spread of PPR."

Among the nuclear-related techniques employed are nucleic acid-based diagnostics and serum-based virus tests, which can be used

to diagnose and monitor PPR, as well as for developing, adapting and validating vaccines and diagnostic technologies and procedures. The laboratories comprising the VETLAB network provide training in these techniques, as well as support in early and rapid diagnosis and control of PPR.

Connect, exchange, contain

The VETLAB network of animal health laboratories connects scientists and laboratories from 40 countries in Africa and 17 in the Asia-Pacific with the IAEA, FAO, OIE and other partners, and helps to ensure that advanced capacities are available to stay ahead of these diseases.

Through this network, scientists share their knowledge to more dynamically adapt strategies and further research and development that is essential to monitoring and containing the spread of transboundary animal and zoonotic diseases. According to Sabenzia Nabalayo Wekesa, Head of the Molecular Laboratory of the Central Vet Laboratories in Nairobi, Kenya, sharing diagnostic data is an important element of the entire animal disease control process. It allows for close collaboration with other countries and helps compare results, learn what diseases are circulating elsewhere, and prevent them from spreading.

In cases where key veterinary capacities are lacking, the VETLAB network facilitates scientific training and assists laboratories through providing equipment and technical support. Laboratories throughout the VETLAB network also offer rapid and early diagnostic and control services to other laboratories that lack the capacity to do this themselves. Together, this translates into more improved national and regional veterinary services and, ultimately, more effective animal disease control.


(Photo: N. Jawerth/IAEA)

THE SCIENCE

Genetic sequencing

Sequencing is a nuclear-derived technique that involves finding the way the nucleic acid (RNA and DNA) information inside pathogens is gathered. Organisms, including viruses, have genetic material. Through genetic sequencing, scientists can find out how the information inside the genetic material is structured and how it behaves. This not only helps to diagnose a disease, but can also disclose its origin and evolution.

Radioactive labelling was the method used for the first molecular characterization of a virus genome, and it is still the preferred technique where high levels of sensitivity and specificity are needed, and where a single pathogen among a million similar micro-organisms has to be identified. However, in most cases, a simpler method, involving a less sensitive labelling approach using dyes, chromophores or mass spectroscopy can be sufficient to identify the pathogen threat.

These nuclear-based tools and techniques are also used for detecting diseases like the Ebola and Zika viruses.

(Photo: M.Gaspar/IAEA)

Myanmar uses nuclear techniques to improve industrial processes

Experts are rolling out the use of nuclear technology in industrial testing across Myanmar, following the successful implementation of the technique in the oil and gas sector. (See The Science box, page 19)

Non-destructive testing (NDT) using nuclear techniques involves the use of ionizing radiation to test the quality of materials and products. It plays a vital role in the production and maintenance of materials and structures, without causing any damage to them or leaving any radioactive residue.

The technique called gamma process tomography used in Myanmar is based on the differential absorption in different materials of gamma rays emitted from a radioactive source.

Since 2013, the IAEA has helped the country's Department of Atomic Energy purchase the necessary equipment and build the expertise of its staff to use the technique. The project was funded through the Peaceful Uses Initiative (PUI). Department experts regularly perform NDT in the Thanlyin oil refinery near Yangon to inspect the quality of pipes as well as of the products flowing in them.

"Nuclear science and technology play a major role in bringing innovation and efficiency to industrial processes," said Meera Venkatesh, Director of the Division of Physical and Chemical Sciences at the IAEA. "Myanmar provides a great example on how low-income countries, too, can take advantage of this technology."

"NDT inspections including those using nuclear applications are crucial in the quality control of various industrial fields in Myanmar."

Ingyin Phyu, NDT researcher, Department of Atomic Energy, Myanmar

Oil pipes, boilers, pressure vessels, buildings, aircraft equipment and ships are among the products whose quality is tested with the technique worldwide, and Myanmar's Atomic Energy Department is taking steps to spread its use, said Ingyin Phyu, the scientist in charge of the Department's NDT laboratory. "NDT inspections including those using nuclear applications are crucial in the quality control of various industrial fields in Myanmar," she said.

Technical staff of Myanmar Railways, Myanmar Shipyards, Yangon Technological University and private companies have recently received training on the use of the technique and have already employed it in a wide range of activities, including on construction sites, in dockyards, on locomotives and at the country's largest amusement park.

"The use of NDT greatly enhances the shipbuilding and ship repair sector," said U Myint Zaw, Deputy General Manager and senior NDT inspector at Myanmar Shipyard. "It is essential for the improvement of our industrial processes and products and we use it extensively for quality control."

In 2017, the IAEA developed a new project to use NDT to support the preparation and recovery of civil infrastructures following natural disasters for countries in Asia and the Pacific region. This project builds on experience gained following the devastating earthquake in Nepal in April 2015 when NDT was used in the aftermath to test the integrity of critical buildings such as hospitals, schools and historical attractions.

THE SCIENCE
Non-destructive testing

Industrial testing using nuclear technology involves the use of ionizing radiation – along with other methods – to test the quality of materials, without causing any damage to them or leaving any radioactive residue. This technique is referred to as non-destructive testing (NDT).

NDT methods include radiography, a type of radiation technology, and gamma tomography, which is based on the differential absorption in different materials of gamma rays emitted from a radioactive source. Through the measurement of the rays that pass through the material without being absorbed, its make-up and structure can be identified. These techniques are able to identify structural defects that cannot be discovered through traditional testing methods.

Industrial radiography is used to inspect, among others, concrete and a wide variety of welds, such as those in gas and water pipelines, storage tanks and structural elements. It can identify cracks or flaws that may not be otherwise visible.

Other commonly used NDT methods include:

- ultrasonic radiography, which uses mechanical vibrations similar to sound waves,
- liquid penetrant inspection, which can locate surface-breaking defects in non-porous materials,
- magnetic particle inspection, which can detect surface and slightly subsurface discontinuities in ferromagnetic materials, and
- eddy current testing, which uses electromagnetic induction to detect flaws in conductive materials.

Cleaning up uranium sites of the past for a safer future

Environmental remediation in Central Asia

Monitoring and managing radioactivity levels and the environment at abandoned uranium production sites across rural Kyrgyzstan, thanks in part to IAEA technical support, is helping to keep the public and environment safe. This work is ongoing at around 10 sites, while further funds for the implementation of long-term remediation plans still need to be secured.

"Many of these sites contain toxic residues, and the possibility of seismic instability, such as landslides, poses the biggest risk to the surrounding environment," said Asel Seitkazieva, Deputy Director at the country's Ministry of Emergency Situations.

"Kyrgyzstan's positive experience with the IAEA could serve as a useful roadmap for future remediation efforts, especially when seeking ways to implement programmes within existing national regulatory frameworks," she said.

According to the Ministry of Emergency Situations of the Kyrgyz Republic, Kyrgyzstan has 35 tailings dumps and 25 sites with waste rock piles.

"Kyrgyzstan's positive experience with the IAEA could serve as a useful roadmap for future remediation efforts, especially when seeking ways to implement programmes within existing national regulatory frameworks."

Asel Seitkazieva, Deputy Director,
Ministry of Emergency Situations, Kyrgyzstan

These uranium sites were built at a time when planning for eventual end-of-life management was not a common practice. For decades, they were used for uranium production (see The Science box, page 23) and were eventually shut down in the 1990s.

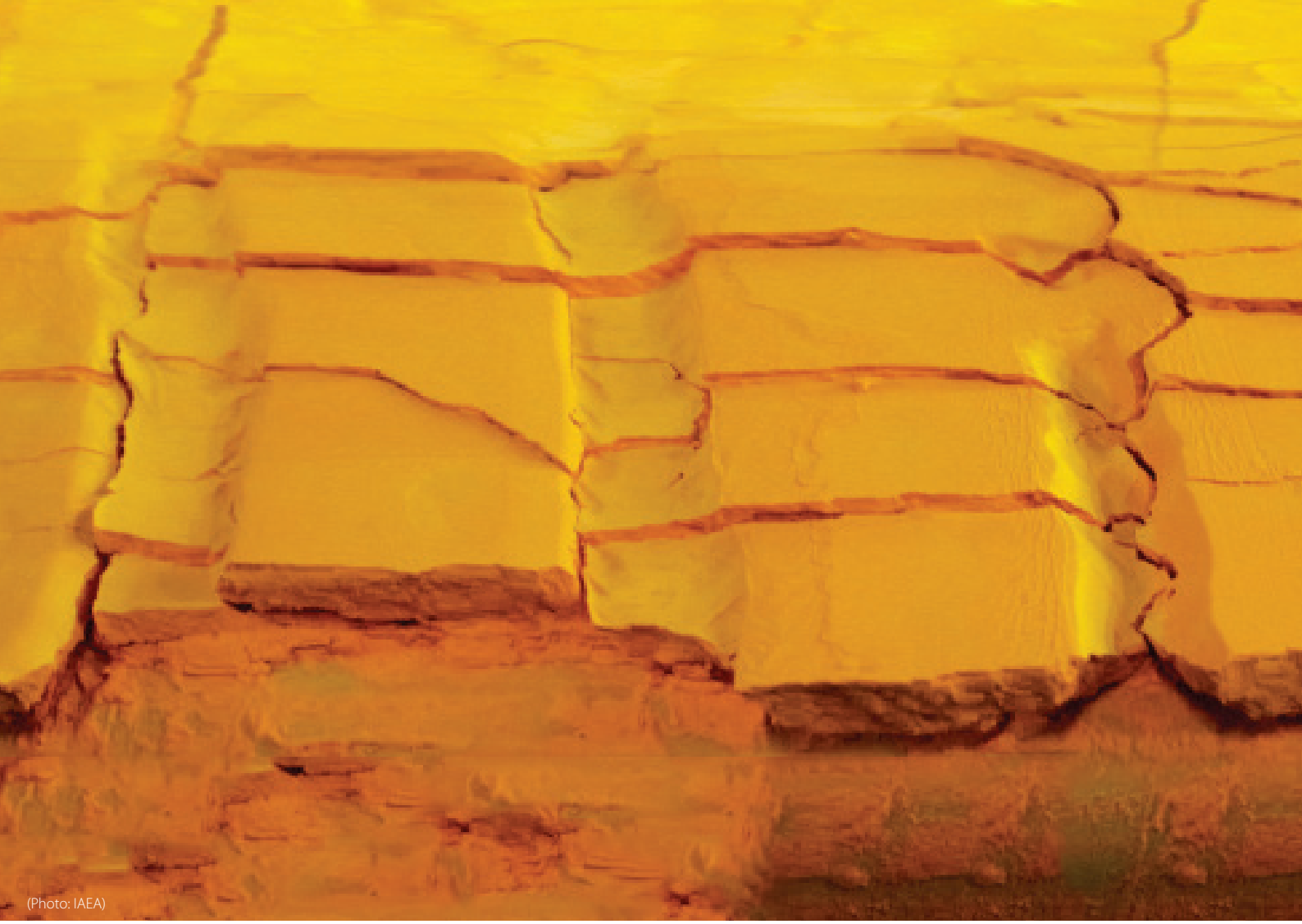
The immediate focus has since been on addressing risks associated with the sites to help protect people and the environment. These risks include leftover residues of long lived radioactive and highly toxic chemical contaminants that pose substantial risks to public health and the environment, as well as flooding and seismic events, such as landslides.

(Photo: IAEA)

"By some estimates, the quantity of uranium production residues in Central Asia — such as waste rock and tailings — approaches one billion tonnes," said John Rowat, Head of the Decommissioning and Remediation Unit at the IAEA Department of Nuclear Safety and Security. "Many of these materials are stored in an unsafe manner at sites scattered across the region. Due to lack of funding, work over the last decade has focused mostly on containment of the toxins in the former mining sites to restore their safety."

Through IAEA technical cooperation projects and financing through the Peaceful Uses Initiative (PUI), specialists from the country's Ministry of Health, the National Academy of Sciences, and the State Agency for Environmental Protection and Forestry have learned to use gamma and alpha spectrometry technology to assess and monitor radiation levels. IAEA-facilitated aid from other international organizations, such as the European Commission, is also helping them to make progress in partially remediating and cultivating waste piles and mill tailings. Several landslide-prone spots near tailings have been improved and re-engineered to reduce the likelihood of instability.

Alongside these immediate actions, environmental remediation plans and projects have been prepared by Kyrgyz authorities through support from the IAEA's Coordination Group for Uranium Legacy Sites (CGULS). While lack of funds has stalled progress on implementing remediation plans, preparing sites by "beginning to transfer tailings to safe zones and beginning to restore other tailings,



(Photo: IAEA)

the groundwork has been set for future remediation. Once further funding is secured, physical transfer of the waste and re-cultivation of the site will take place," Seitkazieva said.

Neighbouring countries can learn from each other

"Kyrgyzstan's experience with IAEA-supported remediation efforts may be helpful for neighbouring countries considering similar projects," said Seitkazieva. Tajikistan and Uzbekistan, for instance, have engaged the IAEA to procure laboratory equipment, arrange training of staff and assist in site characterization exercises, much like what Kyrgyzstan has already done.

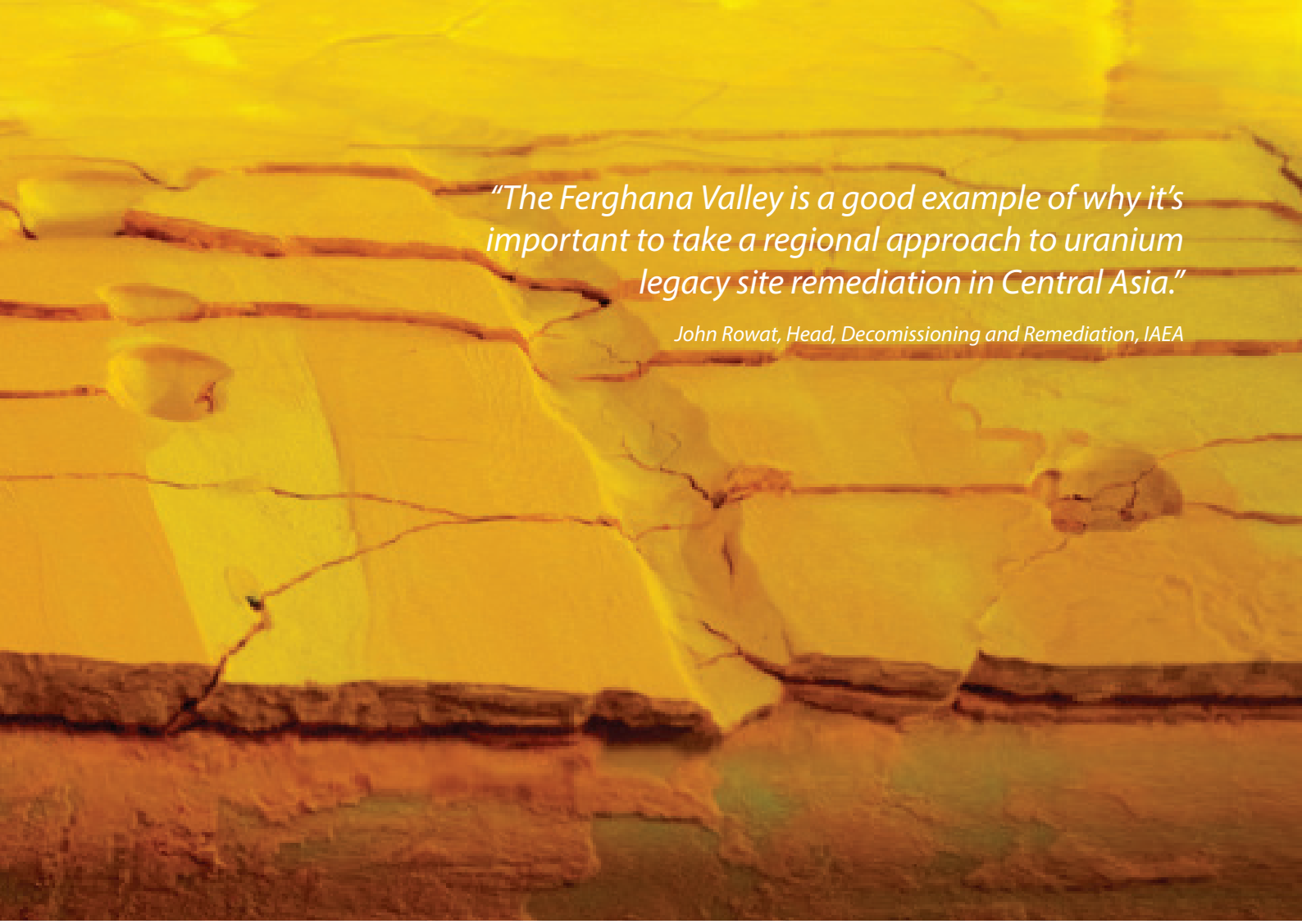
Kyrgyzstan's neighbours often share common challenges when it comes to remediation. Along the border of Kyrgyzstan, Tajikistan and Uzbekistan, a valued agricultural watershed in the Ferghana Valley is under threat of contamination by toxic substances from former uranium production sites.

"The Ferghana Valley is a good example of why it's important to take a regional approach to uranium legacy site remediation in Central Asia, to complement country-specific programmes," Rowat said. The IAEA is working with the three countries to address remediation at the regional level. "Kyrgyzstan, Tajikistan, and Uzbekistan all draw upon the water resources of the Ferghana Valley."

Sustainable today for a better tomorrow

Uranium and associated minerals remain central to nuclear energy production. As countries continue to show an interest in nuclear power, ensuring proper regulatory frameworks and control capacities is essential.

To this end, the IAEA, in part through PUI, has helped countries worldwide to develop a better understanding of how uranium resources can be exploited in a safe and sustainable manner and how to reduce potential problems with uranium legacy sites. This includes helping



"The Ferghana Valley is a good example of why it's important to take a regional approach to uranium legacy site remediation in Central Asia."

John Rowat, Head, Decomissioning and Remediation, IAEA

countries to learn how to safely assess site-specific radiological impact on people and the environment stemming from uranium production, as well as the remediation and long-term management of sites.

Maintaining a sustainable approach to uranium production and the use of nuclear energy also contributes to the Sustainable Development Goals, which were adopted by the United Nations in September 2015.

THE SCIENCE

What is uranium and how is it used?

Uranium is a radioactive chemical element that naturally occurs in rock, soil and water. It is typically mined using open-pit technology when the ore is close to the surface, and using underground mining when it is deeper down. The ore typically contains from around a few hundred parts per million to up to 20 per cent uranium. Globally, close to 60 000 tonnes of uranium are produced annually.

Uranium has six naturally known isotopes, which are atoms that share the same number of protons as uranium, but have a different number of neutrons. Like all radioactive isotopes, uranium isotopes decay, releasing radiation in the process. This radiation can be harnessed for use in a nuclear power reactor for producing energy and in research reactors for scientific studies. It can also be used in, among others, photographic chemicals and certain types of specialized light bulbs, as well as in geology for dating the age of rocks and in the production of high-energy X-rays.

As uranium decays, it forms other chemical elements and isotopes, like plutonium-239. These also serve as sources of radiation that can be used in, among others, nuclear reactors, medicine, food and agriculture and industry.

Safer seafood: IAEA develops tools to help fight algal toxins

When tiny marine organisms grow uncontrolled, forming what is called a harmful algal bloom, their toxins can make people sick, harm ocean life and cause millions of dollars in lost seafood revenues. To help mitigate the effects of these toxins, scientists at the IAEA are working with researchers in Cuba to detect and measure biotoxins in ocean organisms and to develop monitoring and reference tools that will help identify such outbreaks worldwide. The project is funded through the Peaceful Uses Initiative (PUI).

"With a better understanding of how harmful algal blooms behave and how their toxins enter the food chain, it will be easier for countries to monitor toxins and control the consumption of contaminated seafood," said Marie-Yasmine Dechraoui Bottein, a research scientist at the IAEA leading this collaborative project with the Centre de Estudios Ambiantales de Cienfuegos (CEAC) in Cuba. "Harmful algal blooms have a particularly big impact on small island states that rely heavily on their fisheries and tourism."

In Cuba, the fishing and sale of thirteen fish species including groupers, snappers and jacks have been prohibited year-round since 1996 due to a high risk of ciguatera fish poisoning — the most common non-bacterial seafood intoxication caused by ingesting fish that have been contaminated by ciguatera toxin that comes from harmful algal blooms. The toxin is most commonly found in large tropical reef fish. It is only recently that Cuban scientists, with the help of the IAEA, acquired the capability to measure ciguatera toxins in seawater and in fish and shellfish using a nuclear technique called radioligand receptor binding assay (RBA). This method is based on the specific interaction between the toxins and the receptor they bind (pharmacological target), in which a radiolabeled toxin competes for a limited number of receptor binding sites with the toxin in the sample being analysed, allowing quantification of the toxicity of the sample.

Developing reference material

During a recent field mission in Cuba, a team of IAEA scientists and local fishermen collected fish and algae samples at different depths to study the distribution of toxic harmful algal bloom species.

Once the samples have been processed in Cuba, they will be tested at the IAEA's marine laboratory in Monaco. As a result, the IAEA will develop the first-ever reference material for ciguatoxin monitoring worldwide. Such reference materials are critical for national authorities in managing marine environments and adhering to fish trade regulations.

While the exact number of people affected and economic losses are difficult to estimate, the impact of harmful algal blooms is nevertheless considerable. "With these data and reference materials, we can refine how we monitor toxins to help minimize their impact," said Dechraoui Bottein. "It is important to keep in mind that ciguatera fish poisoning remains the most common non-bacterial seafood intoxication worldwide."

“With these data and reference materials, we can refine how we monitor toxins to help minimize their impact.”

Marie-Yasmine Dechraoui Bottein, Research scientist, IAEA

Photo: Iván Hernández Abreras, Cuba

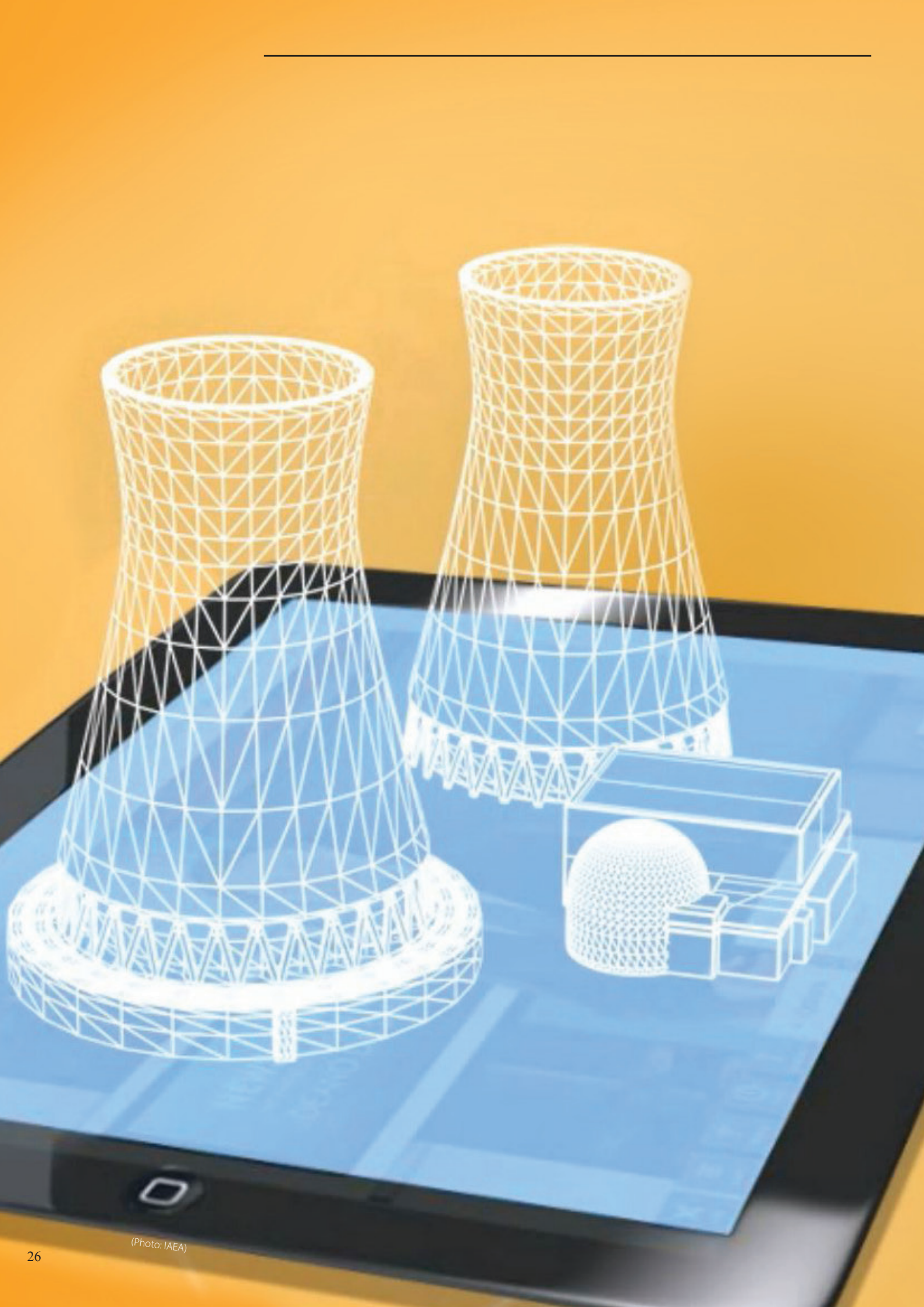
THE SCIENCE

The damage caused by harmful algae blooms

Harmful algal blooms are conglomerations of ocean-borne microorganisms that can be red, blue, pink or even invisible to the naked eye. Under certain circumstances, some species can produce natural toxins such as neurotoxins, which may accumulate in marine fish and shellfish to quantities that are dangerous for human consumption. Eating seafood contaminated with these biotoxins can cause a range of symptoms, from gastrointestinal problems to severe neurological effects and, in rare cases, even death.

Harmful algae bloom outbreaks affect many regions around the world, from the Americas to North Africa to Asia. In the last few years, outbreaks of harmful algal blooms have plagued areas of coastline and inland lakes of the Americas.

For example, in February 2016, harmful algal blooms in Chile decimated 40,000 metric tons of salmon, causing a loss of around $500 million for the local fishing industry as well as a hike in the price of salmon. In 2014, a large bloom in Lake Erie disrupted the water supply of 500,000 Ohio residents for three days.



(Photo: IAEA)

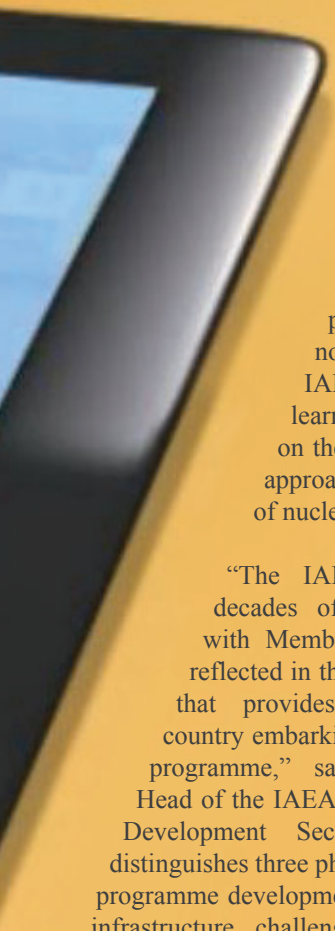
"I have been able to brief senior Government officials in my country on nuclear power using the online modules. The content is well presented and the language is easy to understand."

Emmanuel Wandera, Senior Corporate Affairs and Communication Officer, Kenya Nuclear Electricity Board, Kenya

Putting the 'E' in nucl-e-ar

IAEA develops online learning tools for Member States

Developing a nuclear programme is a major undertaking that requires careful planning, preparation and investment in time, institutions and human resources, and can take at least a decade. Fostering the efficient and safe use of nuclear energy and assisting countries to learn from each other's experience is among the key roles of the IAEA and the Peaceful Uses Initiative (PUI).



To help experts' and policymakers' ease into the complex process of starting and running a nuclear power programme, industry professionals can now access a series of IAEA-developed online learning modules based on the IAEA's "Milestones" approach to the introduction of nuclear power.

"The IAEA has accumulated decades of experience working with Member States, and this is reflected in the Milestones approach that provides guidance for any country embarking on a nuclear power programme," said Milko Kovachev, Head of the IAEA Nuclear Infrastructure Development Section. The approach distinguishes three phases for nuclear power programme development and 19 key nuclear infrastructure challenges to be addressed during the process.

Close to 7400 users from 50 countries, both nuclear "newcomers" and those with existing programmes, have already used the online learning modules, which have been available since 2013.

"I have been able to brief senior Government officials in my country on nuclear power using the online modules," said Emmanuel Wandera, Senior Corporate Affairs and Communication Officer at the Kenya Nuclear Electricity Board. "The content is well presented and the language is easy to understand. For countries with slow internet, the downloading option has made it easier to access and share the modules."

The online portal includes 14 modules that comprehensively explore the ins and outs of nuclear power infrastructure development, covering areas ranging from human resources strategy, to construction management, to how to conduct a feasibility study. Each course begins with a high-level summary targeting decision makers followed by more detailed explanations.

The modules target a variety of stakeholders, including policymakers, advisers and senior government officials, regulatory bodies and operators. The modules can also help researchers, academics and students in the nuclear field better understand the "big picture" of developing nuclear power programmes.

As many of the same principles apply for the infrastructure development for any new nuclear power plant, those involved in expanding existing nuclear power programmes may also find the learning programme to be a valuable resource, Kovachev said.

(Photo: National Atomic Energy Agency (CENA))

Going online to get hands-on

Taking interactive online learning to the next level, the IAEA-supported Internet Reactor Laboratory connects university classrooms in one part of the world to an operating research reactor in another via the Internet.

Using hardware and software installed in the host research reactor, real-time data is sent over the internet to the participating classroom, where students are able to see the live display of the reactor's control panel. Using a video conference link, students can conduct experiments by asking the reactor operators in the control room to change reactor settings and see real-time output. This practical experience enhances their education in nuclear engineering, physics and basic aspects of reactor operation.

Since the launch of the project in 2015, two host institutions and seven guest universities have been engaged.

Argentina's RA-6 research reactor is serving as the hub of the project in Latin America, conducting six experiments a year with guest universities in Ecuador, Colombia and Cuba, said Pablo Cantero of the Argentinean National Atomic Energy Commission (CNEA). France's CEA-ISIS research reactor is the hub for Europe and Africa, broadcasting five experiments a year to Belarus, Lithuania, Tanzania and Tunisia.

The IAEA will continue to enhance Member States' access to online tools and other educational resources. "We have created a single, unified web portal," said John de Grosbois, Head of the IAEA Nuclear Knowledge Management Section. "This one-stop-shop will make it easier for users to find and access all of the IAEA's e-learning material and other training resources."

THE SCIENCE

Nuclear knowledge management

The nuclear industry is knowledge-based and depends on the skills and knowledge of its workforce. For countries operating a nuclear power programme, an ageing workforce coupled with a decline in student enrolment in science and engineering programmes in general and nuclear science in particular has led to a need to intensify efforts to ensure an adequate pool of experienced professionals. They need to be prepared to take on responsibility in senior technical roles and contribute to the management of the nuclear sector.

For newcomer countries that are considering or planning their first nuclear power plant, ensuring nuclear knowledge is built and can be maintained throughout the lifetime of a programme is essential. This knowledge includes governmental, legal, regulatory, managerial, technological, human resource, industrial and stakeholder aspects of developing a nuclear power programme. Ultimately, this specialized knowledge lays the foundation for developing and using nuclear facilities and materials in a safe, secure and peaceful way.

IAEA

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