ATOMS FOR PEACE AND DEVELOPMENT

A special edition of the IAEA Bulletin on peaceful uses of nuclear technology

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The International Atomic Energy Agency’s mission is to prevent the spread of nuclear weapons and to help all countries — especially in the developing world — benefit from the peaceful, safe and secure use of nuclear science and technology.

Established as an autonomous organization under the United Nations in 1957, the IAEA is the only organization within the UN system with expertise in nuclear technologies. The IAEA’s unique specialist laboratories help transfer knowledge and expertise to IAEA Member States in areas such as human health, food, water and the environment.

The IAEA also serves as the global platform for strengthening nuclear security. The IAEA has established the Nuclear Security Series of international consensus guidance publications on nuclear security. The IAEA’s work also focuses on helping to minimize the risk of nuclear and other radioactive material falling into the hands of terrorists, or of nuclear facilities being subjected to malicious acts.

The IAEA safety standards provide a system of fundamental safety principles and reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards have been developed for all types of nuclear facilities and activities that serve peaceful purposes, as well as for protective actions to reduce existing radiation risks.

The IAEA also verifies through its inspection system that Member States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements to use nuclear material and facilities only for peaceful purposes.

The IAEA’s work is multi-faceted and engages a wide variety of partners at the national, regional and international levels. IAEA programmes and budgets are set through decisions of its policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States.

The IAEA is headquartered at the Vienna International Centre. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.
Atoms for peace and development: contributing to global progress through nuclear science and technology

By Yukiya Amano, Director General, IAEA

Cultivating new crop varieties, reducing soil erosion and helping African countries respond to Ebola Virus Disease are just some of the areas in which the IAEA helps Member States to benefit from nuclear technology. Assisting countries in the safe and secure use of nuclear techniques 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.

Our mandate has been summarized as Atoms for Peace. Today, I feel that our mandate could be better understood as Atoms for Peace and Development.

This is a milestone year for global development as the international community takes stock of the progress made towards achieving the Millennium Development Goals and finalizing the post-2015 Sustainable Development Goals. World leaders have called for an ambitious post-2015 agenda that provides a long-term plan to improve people’s lives and to protect the planet for future generations.

Science and technology are critical for development. They need to be recognized as an important enabler of the post-2015 development agenda. Nuclear science and technology, in particular, have an enormous contribution to make. The IAEA plays a unique role in making nuclear science and technology available to improve the lives of people everywhere. I have been working hard to improve recognition of the important role played by the IAEA in this area.

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 booklet, we illustrate the impact of the IAEA’s work through 16 examples spanning the wide range of our activities.

You will read of the farmer in Mauritius who can now grow high-quality cash crops, the Senegalese cattle herder whose cows are healthier than ever before, the Guatemalan health official who can now diagnose malnutrition and recommend treatment to children at an early age, and the Romanian priest who saved the beautiful iconostasis of his church from being destroyed by insects. All of these were made possible through the application of nuclear science and technology to everyday problems.

The IAEA also provides support to activities related to nuclear power programmes. We assist Member States which are considering adding nuclear power to their energy mix so that they can use it efficiently, safely and securely. Our work in this area is illustrated by stories on sustainable uranium mining in Tanzania, nuclear power infrastructure development in Turkey, the safe handling of radioactive waste in Morocco, and increased nuclear security through the conversion of a research reactor in Kazakhstan.

Membership of the IAEA continues to grow and demand for our services in all areas of nuclear sciences and applications is increasing steadily. The IAEA Peaceful Uses Initiative has been an effective mechanism in raising additional resources for the IAEA to meet this growing demand. I hope to be able to continue with this valuable initiative in the future.

I trust that you will find that this booklet provides a valuable insight into the very special work of this unique organization.

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Photos: D. Calma/IAEA
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Nuclear science and technology can help find solutions to many of the problems people face every day across the globe. When used safely and securely, nuclear science and technology are effective supplements or provide alternatives to conventional approaches, which makes them an important part of the international community’s work for development. In its contribution to global objectives, the IAEA serves the international goals of peace, health and prosperity by assisting countries to adopt nuclear tools for a wide range of peaceful applications.

Within the context of global trends and development, IAEA services — some highly visible on the global stage, others delivered more discreetly — underpin collective efforts for the safe, secure and peaceful use of nuclear science and technology. They are supported by the IAEA’s specialized laboratories in Seibersdorf, Austria, and in Monaco, as well as dedicated programmes, networks and collaborations with partners. Through the IAEA’s assistance, nuclear techniques are put to use in various areas, including human health, food and agriculture, the environment, water, energy, nuclear safety and security, and the preservation of artefacts.

Human health
Health is of critical importance to people’s lives and to achieve sustainable development. For low-income families, poor health can reinforce cycles of poverty. To increase access to health care, the IAEA and its specialized laboratories support IAEA Member States, in particular in low and middle income (LMI) countries, with assistance in the form of equipment, expert guidance and training, and knowledge exchange to aid in the use of nuclear techniques for diagnosing, treating and managing cancer, cardiovascular and other non-communicable diseases. This work also includes ensuring the safe and secure use and management of radioactive sources, such as those used in radiotherapy machines and for sterilizing medical tools, as well as the safe and secure production, availability and use of radiopharmaceuticals — drugs that contain radioactive substances — used in nuclear medicine and radiation therapy.

Good health also relies on proper nutrition and adequate access to food. Nuclear techniques can be applied to monitor and sustainably address malnutrition — from severe malnourishment to obesity — and to implement breastfeeding programmes to improve nutrition and health from the first days of life. The IAEA helps many countries with training and the provision of the equipment necessary to conduct these nutrition-related projects.

Food and agriculture
A number of countries, particularly those relying heavily on agriculture for food and livelihoods, are turning to nuclear techniques to enhance agricultural productivity and food security and safety. IAEA projects and programmes help to provide important equipment and expert guidance, as well as technology and training from the IAEA’s specialized laboratories and partner organizations like the Food and Agriculture Organization of the United Nations (FAO). With this support nuclear techniques can be used by countries safely and properly, in such areas as, breeding improved crop and plant varieties, including vitamin or mineral-enriched varieties; controlling animal and plant pests and disease; improving food safety; enhancing livestock reproduction and nutrition; and strengthening soil and water management.

Environment
Food and agricultural development are often affected by adverse environmental conditions. This can pose serious challenges for many countries, in particular in LMI countries with economies that are reliant on agriculture. With the IAEA’s support, many countries use nuclear and isotopic tools to research and address environment-related matters. They can evaluate the impact of changing environmental conditions due to natural or man-made causes, as well as monitor pollution, its trends and manage its impacts.
Access to safe water sources is essential to supporting growing populations, accelerating economic development and meeting the demands of changing lifestyles. The quality of ocean water not only impacts marine life, but also affects those people who rely on the sea for their livelihoods. Many countries have now turned to the IAEA to assist them in using nuclear and isotopic techniques to better understand water in order to sustainably manage and protect them for the future.

**Nuclear energy**

In the face of climate change and increasing demands for electricity, some countries are now assessing or planning to include nuclear power as part of their energy mixes. They look to the IAEA for support to do so safely, securely, economically and sustainably. The IAEA assists these countries to do so in line with internationally recognized safety and security standards, best practices and relevant legal instruments including respective nuclear non-proliferation obligations.

The IAEA’s assistance also facilitates the safe and secure transport, handling and use of radioactive materials in fuel cycle technologies, radioactive sources for energy production and other radiation-related purposes. This support also includes facilitating the proper and sustainable mining of essential chemical elements for nuclear energy production, as well as the effective decommissioning and management of nuclear facilities, radioactive waste and spent fuel from cradle to grave.

Behind each IAEA project, programme and service lies a foundation of safety and security, which is undertaken in line with international safety and security standards. The IAEA provides Member States with the assistance they need when they embark on using nuclear science and technology, through review services and facilitating tailored, dedicated training and emergency preparedness exercises. Ensuring that these uses remain peaceful and are properly managed in order to protect people and the environment while achieving the full benefits that these tools offer, are paramount attributes of the IAEA’s services that are made available to Member States.

What is the Peaceful Uses Initiative (PUI)?

The IAEA Peaceful Uses Initiative (PUI), launched in 2010, has become instrumental in raising extrabudgetary contributions which supplement the Technical Cooperation Fund to support technical cooperation projects and other unfunded projects of the IAEA in the areas of peaceful application of nuclear technology. Additional resources made available through the PUI have served to enhance the IAEA’s ability to fulfil its priorities and statutory responsibilities, and to meet the needs of Member States. Extrabudgetary contributions made through the PUI have been used to support a wide variety of IAEA activities aimed at promoting broad development goals in Member States, such as in the areas of food security, water resource management, human health, nuclear power infrastructure development and nuclear safety, many of which would have remained unfunded otherwise.

The PUI has also allowed the IAEA to be more flexible and quicker in responding to shifting priorities of Member States, as well as to unexpected needs or unforeseen emergency events, as demonstrated in the aftermath of the Fukushima Daiichi accident as well as the Ebola virus disease outbreak in western African States. To date, the PUI has helped raise over €60 million in financial contributions from 13 Member States and the European Commission, in support of more than 170 projects that benefit more than 130 Member States.
Bringing cancer care closer to home: Mauritania opens first nuclear medicine centre

By Omar Yusuf

The opening of the Islamic Republic of Mauritania’s first ever nuclear medicine centre with IAEA support in late 2014 will lead to improved access to modern diagnostics and treatment, as well as lower costs. The new facility is part of the country’s National Oncology Centre, which opened in 2010, with support from the IAEA. The centres offer comprehensive services in diagnosing, treating and managing cancer and other diseases in Mauritania and the surrounding region.

The country has come a long way in cancer care over just a few years, said Moustapha Mounah, Director of the National Oncology Centre. “There were huge challenges ahead of us. We had no infrastructure, no equipment and no human resources to treat our patients,” he said. “Now, after four years, Mauritania is able to provide radiotherapy and nuclear medicine services, with very sophisticated materials, and operated by Mauritanians.”

Local access has made life easier for patients

“Before working with the IAEA we had no radiopharmacy technicians, and we sent all our cancer patients to Morocco, Tunisia or elsewhere. However, now we treat practically all our patients locally,” said Abdoulaye Mamadou Wagne, a radiotherapy technician at the National Oncology Centre.

Nuclear medicine and radiotherapy are two key areas of medicine that use radiation and atoms that emit radiation, known as radionuclides, to diagnose, treat and manage diseases (see box).

Facing cancer head-on

Cancer kills more than 7.6 million people every year — more than HIV/AIDS, tuberculosis and malaria combined. It is increasingly recognized as a major public health problem across Africa. The burden of the disease has worsened as rising living standards have led to lifestyle and environmental changes, such as unhealthy diets, pollution and physical inactivity, that increase the incidence of cancer.

For many years, Mauritania, one of Africa’s 34 least developed countries, has struggled to address the financial and human costs related to cancer. Haematological malignancies and solid tumours, for example, require specialized treatments that were not available at Mauritanian hospitals, requiring patients to seek treatment abroad. Cancer of the cervix, breast, prostate, liver and ovary are among the most common in the country.

Today, the two centres provide radiotherapy and nuclear medicine services using a linear particle accelerator and a high dose rate brachytherapy machine. They also employ more than 20 medical professionals trained through IAEA fellowships, training courses and expert visits.

“We are very enthusiastic about this relationship [with the IAEA], which has begun to deliver very positive results in a very short time,” said President of Mauritania, Mohamed Ould Abdel Aziz.
at the inauguration of the new facility in December 2014. “In terms of medical treatment of cancer, we are now in a fairly comfortable position.”

The National Oncology Centre is now planning to share the new know-how with neighbouring countries, so that cancer diagnosis and care can improve throughout the Sahel region. “We have plans to ensure that our centre becomes a reference centre and a training centre for the region,” Mounah said. “We are becoming a centre whose work is comprehensive and which is exceptionally well-equipped.”

Supporting transformation through cooperation

The IAEA has supported Mauritania since 2004 through its technical cooperation programme, assisting the government to transform the country into a nation able to safely and cost-effectively use nuclear techniques. The country now uses nuclear technologies and tools to fight pests and animal disease, map water tables underground, as well as monitor and measure radiation dose levels to protect health care professionals, the public and the environment from ionizing radiation. It is also training engineers and economists to use energy planning tools and databases related to nuclear energy.

Although Mauritania still has plenty to do, the country has made great strides in a few short years, giving patients access to better care closer to home that will undoubtedly support the fight against cancer, President Abdel Aziz said. “We believe that in the future this important relationship for our country, and a model in the subregion, will continue to evolve. Given these developments, we are very confident that things will continue to improve,” he said.

THE SCIENCE

Nuclear medicine and radiotherapy

Cancer that was once considered unmanageable and fatal can now be diagnosed earlier and treated more effectively using nuclear techniques, giving patients a fighting chance and, for many, a significant chance for a cure.

Nuclear medicine uses tiny amounts of radioactive substances called radioisotopes for the diagnosis and treatment of some health conditions. Some of the procedures are performed outside of the body, while others, with the help of radiopharmaceuticals that contain the radioisotopes, are absorbed into a patient’s body resulting in a net benefit. The small amounts of radiation emitted by the radioisotopes in the radiopharmaceuticals can be tracked by special cameras that create images of the specific tissues or organs under investigation. Some diagnostic imaging techniques, like X-rays, reveal static pictures of different body parts, while others, like positron emission tomography, can reveal the dynamics of how the body functions.

Radiation therapy, or radiotherapy, uses beams of radiation or radiation sources to target and kill cancer cells. When the therapy is applied to a cancerous growth or tumour, it is reduced in size or, in some cases, disappears altogether. Radiopharmaceuticals can also be used at higher dose levels to provide treatment. Careful calibration of these different therapy techniques help to target cancer cells while minimizing the radiation exposure to healthy cells.
Health

Eating better: Guatemala works to control the double burden of malnutrition

By Aabha Dixit

With the help of nuclear techniques, scientists and health workers in Guatemala are now able to identify the causes and consequences of malnutrition in the country’s children, enabling policymakers to devise strategies to combat obesity and stunting.

The country has one of the highest rates of chronic malnutrition in the world, and tackling it is a key priority for the government, said former Social Development Minister Lucy Lainfiesta. “The Guatemalan Government’s proposal for fighting chronic malnutrition will emphasize the window of opportunity found in the first 1000 days of life, through interventions that will ensure that mother and child have what they need to be well nourished,” she said.

Projects using isotope technology to assess nutritional status are “beginning to make a positive and noticeable impact in our nutrition programmes,” said Manuel Ramirez, Coordinator of the Research Centre for the Prevention of Chronic Diseases, from the Institute of Nutrition of Central America and Panama (INCAP), Guatemala.

“Nuclear science and technology gave us the tools to understand and associate body composition with physiological changes, which can help to prevent disease later in life.”  
— Manuel Ramirez, Coordinator, Research Centre for the Prevention of Chronic Diseases, Institute of Nutrition of Central America and Panama (INCAP), Guatemala

Measuring children’s total body water using isotopic tracers helps to determine their body composition, and the percentage of fat in their body, which in turn allows specialists to prescribe the right diet (see box).

The IAEA’s support has helped Guatemala and other Member States to have the necessary information and data to design or improve their nutrition programmes. These include increasing the intake of vitamins and minerals through food fortification or micronutrient supplementation, complementing advocacy for healthy eating, and increased physical activity.

Fewer tortillas, more carrots

Lack of protein and micronutrients in diets, composed mainly of high carbohydrate foods, is a major reason for malnutrition in Guatemala, according to Ramirez. Health workers have noticed that in rural areas, children between six months and three years of age regularly eat corn tortilla softened with caffeinated drinks. This food is not beneficial for infants and young children, who should instead eat healthier locally produced food like eggs, avocado, bananas, soft cooked vegetables, beans, rice and oatmeal. Poor quality diets in infancy can lead to obesity later in life. With the help of nuclear techniques, scientists are able to track the amount of protein absorbed by the body and make diet recommendations accordingly, keeping in mind the availability of ingredients locally, explained Christine Slater, Acting Head of the Nutrition Section at the IAEA.

While obesity is the main health challenge among children in the cities, in rural areas, the indigenous population mostly suffers from the opposite problem. Nearly eight out of ten indigenous children are stunted, compared to just four out of ten non-indigenous children, Ramirez said. The latest research results have clarified that, contrary to popular belief, the short stature
of indigenous Guatemalans is not due to genetics. It is caused by inappropriate feeding practices and poor diet in the early years of life, he said.

Stunting is a major contributor to poverty, Ramirez said. Stunted children face learning difficulties, which prevents them from earning well later on in life. There is an urgent need to ensure that diverse nutritious diets are available and accessible.

While all stunted children need adjustments to their diets, nuclear techniques can help determine how their diets should be changed, Slater said. “There is a growing realization that measuring the weight and height of children is not enough,” Slater explained. “We need to understand body composition in order to determine healthy growth.”

Children who are obese, stunted or both tend to lead less healthy lifestyles and suffer more health problems later in life, Ramirez said. “These children walk less, have lower oxygen consumption and poor blood circulation,” he said.

With the information and data collected under IAEA projects, a task force endorsed by eight health ministers from Central America was established in June 2014 to develop a regional policy on the prevention and management of obesity in children and adolescences.

### THE SCIENCE

#### Using isotopes to measure body composition

Stable isotopes can be used to measure the amount of water and nutrients in the body and the amount of ingested nutrients the person’s body absorbs. They can also be used to measure the rate of absorption, utilization or synthesis of proteins, fats or carbohydrates. Stable isotopes are non-radioactive, so there is no radiation hazard associated with their use.

Stable isotope labelled compounds are absorbed and behave in the body in the same way as their unlabelled counterparts, but because they have a different molecular mass, they are traceable. For example, to measure the percentage of water and fat in the body, a person is given a drink of special water, rich in deuterium, which is a stable isotope of hydrogen. Isotopes of an element have the same number of protons, but one or more extra neutrons, giving them a heavier molecular mass.

A few hours after a person drinks a small, carefully weighed amount of water with deuterium isotopes \( (D,O) \), the deuterium is evenly spread through the body water. The body water can then be sampled in the form of saliva or urine, and the amount of deuterium measured.

Because technicians know the amount of labelled water they gave the patient and subsequently measured the amount and proportion of labelled molecules in the body water, they can calculate how much water there is in the body. From this they can calculate the amount of lean, or non-fat, tissue by knowing that water forms 73 per cent of the lean tissue weight. The difference between the body weight and the amount of lean tissue is the amount of fat. Depending on how the fat content differs from the norm, they can prescribe the relevant diet or advice concerning physical activity.
Health

South Africa improves exclusive breastfeeding monitoring using nuclear technique

By Sasha Henriques

Babies in South Africa that would once be at high risk of malnutrition, disease and even death, now have brighter futures as nuclear techniques help mothers become more diligent about exclusive breastfeeding for the baby’s first six months.

Breastfed children are more resistant to disease and infection compared to formula-fed children, points out the World Health Organization, which recommends that from birth up to six months of age babies should drink only breast milk. Research indicates that breastfed babies are less likely to develop diabetes, cardiovascular disease and cancer later in life.

“South Africa has very poor exclusive breastfeeding rates and improving breastfeeding practices in order to reverse the dismal infant mortality rates in our country has now become an urgent priority,” said Anna Coutsoudis, Professor in the Department of Paediatrics and Child Health at the University of KwaZulu-Natal in South Africa.

Healthcare practitioners, especially those in developing countries, have been promoting this concept in clinics, health centres and maternity wards in order to prevent malnutrition, disease and eventually death in infants.

Health officials in South Africa thought their efforts were successful, because research — which relied on mothers’ self-reports of breastfeeding frequency — showed a significant increase in numbers. However, the infant mortality rate did not show a commensurate drop.

In 2013, around 1.1 million babies were born in South Africa, and 33 babies out of every 1000 live births ended up dying within a year, according to the country’s official statistics. Something was not right.

Nuclear lie detector

In 2010, researchers in South Africa, with funding and support from the IAEA, started using a nuclear non-radioactive method called the deuterium dilution technique (see box) to get accurate figures about how many babies were being exclusively breastfed, and when complementary foods were being introduced into babies’ diets.

The results were distressing and showed that the mothers’ reports of exclusive breastfeeding were a large overestimation compared to the more accurate information that was obtained by using the deuterium dilution technique, said Coutsoudis.

Having IAEA training and support in acquiring equipment to use this technique made it possible for Coutsoudis and her team of health researchers to more accurately assess the impact of programmes designed to improve the poor exclusive breastfeeding rates, which were estimated to be 6 per cent at three months old and only 1 per cent at three months.
six months old, according to a 2008 study in KwaZulu-Natal.

“In 2012, we instituted a long term mentoring programme with new mothers who were simultaneously trained as breastfeeding counsellors. The deuterium dilution technique was used to validate reported breastfeeding practices. We were able to show that the mentoring and counselling programme had a big impact on improving exclusive breastfeeding rates,” said Coutsoudis. By the end of the programme, exclusive breastfeeding rates had improved significantly, to 33.3 per cent at three months and 13.7 per cent at six months.

The new mentorship and counselling programme has been so effective that Coutsoudis said there are mothers resisting the strong external pressure to introduce complementary foods too early.

Here are the accounts, as told by Coutsoudis, of Ms K and Ms C:

“Ms K said, ‘My friends came to visit me at my house and asked “what porridge are you feeding your baby as she is so fat and looks so good”. I replied: ‘I am not giving porridge, only breast milk.’ Her friends did not believe her so they looked in her cupboard to see if she had any porridge and there was none. She proceeded to inform them very casually about how all mothers can produce a lot of milk to feed their babies on breast milk only in the first six months by feeding the baby often – every 2 to 3 hours when they are small.”

“Ms C said she went to the clinic for her immunization visit and the sister [nurse/healthcare worker] told her that her baby was too fat and she should stop breastfeeding, she told the sister she was only giving the baby breast milk and you can’t overfeed a breastfed baby so she was not going to feed her baby less.”

**THE SCIENCE**

**Deuterium dilution**

The mother drinks water labelled with deuterium, a stable, non-radioactive isotope of hydrogen (D₂O). The deuterium mixes with the water in the mother’s body, including her milk, and enters the baby when it suckles. The saliva of the mother and baby then contains deuterium. Over the next two weeks, scientists regularly collect samples of saliva and measure the deuterium content. How much deuterium they find is directly proportionate to how much breast milk the baby has ingested.

The technique also shows if the baby has ingested anything other than human milk over the test period.

“A mathematical model is used to determine how much of the deuterium given to the mother appears in the baby’s saliva. This is related to the amount of human milk consumed by the baby. The mathematical model also gives an estimate of the amount of water from sources other than the mother’s milk, and therefore whether or not the baby is exclusively breastfed,” said Christine Slater, Acting Head of the Nutrition Section at the IAEA.
Ensuring quality while going local: IAEA helps Cuba produce radiopharmaceuticals

By Nicole Jawerth

Cancer and cardiovascular disease are health conditions Cuba will now be able to more readily diagnose and treat thanks to its newly built facility for producing key radiopharmaceuticals. Nuclear medicine requires a constant and reliable supply of these radioactive drugs, prepared according to what the industry calls good manufacturing practices (GMP), and there have so far been limitations in getting them to the island nation.

“First, it was Cuba requesting the support with fellowships and expert training, but now we are providing training to fellows in radiopharmaceuticals and generator production.”
— René Leyva Montaña, Director of Production, CENTIS, Cuba

“Through our work with the IAEA, we now have a dedicated GMP compliant facility and the expertise to meet most of our national needs for diagnostic and therapeutic radiopharmaceuticals for helping patients,” said René Leyva Montaña, Director of Production at the Isotope Centre (CENTIS), Cuba’s centre dedicated to radiopharmaceutical production.

GMP follow a series of international quality-assurance standards designed to protect patients from bad quality products. The standards outline the requirements to ensure that the pharmaceuticals produced are of a high quality, safe and effective, and that they contain the correct potency. “Becoming GMP compliant is a demanding, but important process, as a facility must be designed to ensure quality since the products have to be prepared already ready for patient use,” said Joao Osso, Head of the Radioisotope Products and Radiation Technology Section at the IAEA.

Cuba’s new facility will produce generator-based radiopharmaceuticals (see box) with yttrium-90 (Y-90), a key component in nuclear medicine to treat liver cancer and other conditions. Y-90 is produced from its parent isotope, strontium-90 (Sr-90). Sr-90 is a radioisotope, which means it is a radioactive element that decays towards stability. As it slowly decays, it releases Y-90, another radioisotope that has a much shorter decay time. Using special devices called generators, Y-90 can be ‘milked’ from the Sr-90 inside the generator. The Y-90 is then quickly purified and tagged to specific molecules to be used in nuclear medicine.

“Being able to produce the Y-90 generators in the country is much more economical and feasible than buying completed products abroad, as Y-90 has a short decay time, which makes it very difficult and costly to transport,” said Osso, adding that Cuba will still need to buy raw materials, like the Sr-90, from suppliers abroad.

The IAEA has supported Cuba in developing the GMP compliant facility by providing the technical assistance and training needed for the development and production of Y-90, including labelling, quality control, metrology, safety and security, Osso said. Cuba has also received IAEA assistance and funding to buy analytical, radiological protection and metrology equipment and the materials required.

At this stage, CENTIS is preparing different formulations of Y-90 for diagnostic and therapeutic radiopharmaceuticals that can soon go to clinical trials and later to patients, explained Leyva Montaña. The facility is now waiting for the final licensing approval before it is ready for full-scale production, Leyva Montaña added.
Cuba will soon have good manufacturing practices compliant facilities able to produce Mo-99/Tc-99m generators. (Photo: CENTIS)

**Tackling an international supply problem**

In contrast to Y-90 and Sr-90, which are widely available, technetium-99m (Tc-99m), another radioisotope of importance to Cuba and much of the world, is facing international supply problems due to production issues with its parent radioisotope, molybdenum-99 (Mo-99).

“Tc-99m is the ‘workhorse’ of nuclear medicine. Over 70 per cent of all nuclear medicine studies carried out all over the world use this single isotope,” Leyva Montaña explained. Global supply problems with Tc-99m began in the late 2000s due to production stops by two nuclear reactors responsible for two-thirds of the world’s supply of Mo-99. The challenges with these reactors and the limited production capabilities of other countries impact the availability of supplies, said Osso. Strict air transport regulations related to transporting radioactive material has also created challenges with moving international supplies particularly to islands such as Cuba, Leyva Montaña added.

“One of the main problems for Cuba that may arise from the supply issues is the price increase of Mo-99. As the prices go up, we would eventually not have the funds to import all that is needed, and consequently, patients would not receive the assistance they need,” said Leyva Montaña. “Until now, though, the international supply problems have not had a significant effect on Cuba, but we expect there could be an impact so we are working on solutions now to try to mitigate that.”

One of Cuba’s approaches to mitigate supply challenges has been to collaborate with the IAEA in finding new suppliers of Mo-99, as well as to develop its own facilities to produce the Mo-99/Tc-99m generators, Leyva Montaña said, adding that the benefits will trickle down to other islands in the Caribbean. “The project will have a very positive impact on Cuba, and will also prepare Cuba to give the necessary support to small countries in the region.”

Cuba’s role in the region and internationally has changed since the country began collaborating with the IAEA, said Leyva Montaña. “First, it was Cuba requesting the support with fellowships and expert training, but now we are providing training to fellows in radiopharmaceuticals and generators production, supporting IAEA coordinated research projects, and facilitating exchanges and cooperation with several countries internationally.”

**THE SCIENCE**

**Radiopharmaceuticals**

Radiopharmaceuticals are medical drugs that contain small amounts of radioactive substances called radioisotopes. Radioisotopes are atoms that emit radiation. The radioisotopes used in radiopharmaceuticals can be produced by irradiating a specific target inside a nuclear research reactor or in particle accelerators, such as cyclotrons. Once produced, the radioisotopes are tagged on to certain molecules based on biological characteristics, which then result in radiopharmaceuticals.

Once inside a patient’s body, the different physical characteristics and biological properties of radiopharmaceuticals cause them to interact with or bind to different proteins or receptors. This in turn means that the drugs tend to concentrate more in specific body parts depending on that area’s biological characteristics. Therefore, using special cameras, doctors are able to precisely target areas of the body to examine or treat by selecting specific types of radiopharmaceuticals. If the radioisotope emits particulate radiation the radiopharmaceutical may also be used in therapeutical applications.
On stable ground: tackling soil erosion with nuclear techniques in Viet Nam

By Miklos Gaspar

Da Thanh Canh never studied physics or chemistry in school, but he understands a thing or two about nuclear isotopes. Until a couple of years ago, much of his five-acre farm on the hills of central Viet Nam was gradually sliding away. Thanks to nuclear techniques used in determining the exact cause and source of soil erosion, his land is now stable, and his coffee plantation profitable. “We were very worried as uncertainty loomed,” he said. “A few centimetres of the soil disappeared every year when we had big hail storms.”

Thanh Canh is not alone. Soil degradation affects 1.9 billion hectares of land worldwide, close to two thirds of global soil resources.

Soil erosion is the main contributor to land degradation globally, leading to an annual loss of 75 billion tonnes of fertile soil, with an economic cost of about US $126 billion per year. The IAEA, in partnership with the Food and Agriculture Organization of the United Nations (FAO), helps scientists and farmers in measuring and controlling soil erosion through the use of various nuclear techniques. These include using fallout radionuclides, which help to assess soil erosion rates, and compound specific stable isotope analysis, which assists in tracing hot spots of land degradation (see box).

Erosion’s vicious cycle

Erosion affects the top — most fertile — layer of the soil. It also carries away much of the fertilizer used in agriculture and deposits it in fresh water, where the fertilizer feeds algae, which sharply decrease water quality. “It is a double blow,” said Mohammad Zaman, a soil scientist at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

Intensive agriculture, along with deforestation, is a common cause of erosion, Zaman explained. Aggressive farming removes the organic matter that binds the soil particles together, leaving the area vulnerable to erosion during heavy storms. Nuclear techniques help identify erosion hot spots, enabling follow-up mitigation measures to focus on areas most at risk. “As a result of our work, treatment is more targeted, more effective and as a result cheaper,” Zaman said. Following the impact of the project in various Asian countries, the IAEA is now working to replicate its success in other parts of the world and is forming a network of national experts to share best practices and know-how.
Measuring erosion to find solutions

In Viet Nam, where three quarters of the country’s territory is sloping land, erosion is a major problem. An FAO/IAEA pilot project in Lam Dong province in Viet Nam measured soil erosion rates using nuclear techniques at 27 sites. Adopting appropriate conservation practices such as intercropping, creating basins near coffee trees to trap water, and building terraces, led to a 45 per cent reduction in soil erosion, said Phan Son Hai, Director of the Centre for Environmental Research and Monitoring at the Dalat Nuclear Research Institute, which has participated in the project since 2012. Similar results were achieved throughout the region (see chart). Son Hai is now assisting colleagues across the country to introduce nuclear techniques for erosion monitoring nationwide.

In Malaysia, which is also part of the project, Othman Zainudin has been monitoring an area of high erosion in Perlis State, in the northern part of the country, for over ten years, and switched to using nuclear techniques two years ago. “With the new techniques we can obtain much more detailed information,” said Zainudin, who teaches geomorphology at the Sultan Idris Education University in northern Malaysia. Previously, his team could only measure sedimentation rates in lakes, but could not identify the exact source of the sediments, he explained. “Now that we know where precisely erosion comes from, we can undertake proper mitigation measures,” Zainudin said. Later this year, in cooperation with the State Agriculture Department, he will organize a training programme for farmers on techniques to reduce soil erosion. “We could not have done such a knowledge transfer programme before because we did not know the precise source of erosion,” he said.

As for Dao Thanh Canh in Viet Nam, his income has increased by over 20 per cent, with tea plants and animal fodder growing in erosion hot spots among his coffee trees. He is no longer uncertain about the future and feels free to spend his extra income, he said. Much of his extra money is now going toward schooling for his four children. “I am determined to offer them the education I could never get,” he said.

THE SCIENCE

Fallout radionuclides and compound specific stable isotope analysis

Fallout radionuclides (FRNs) originate mostly from nuclear weapons testing and were dispersed over a large area around the world. They are present in the atmosphere and are deposited on the soil surface through rain.

FRNs can help to identify changes in soil redistribution patterns and rates in large catchment areas and to evaluate the efficiency of soil conservation measures in controlling soil erosion. FRNs can be measured non-destructively and relatively easily using modern high-resolution gamma spectrometry.

The compound specific stable isotope (CSSI) technique is used to identify where eroded soil originated because CSSIs are specific to different plants. By studying the CSSI make-up of the eroded soil, scientists can trace it back to its origins.

Combining both approaches provides a strong link between the sediment in the catchment and its source of erosion.
Eradicating tsetse flies: Senegal nears first victory

By Aabha Dixit

After a four-year eradication programme including nuclear techniques, the Niayes region of Senegal is now almost free of the tsetse fly, which used to decimate livestock.

“I have not seen a single tsetse fly for a year now,” said cattle farmer Oumar Sow. “This is in contrast to earlier, when they increased in numbers, especially during the cold season. The flies were really a nuisance to our animals and we had to carefully select the time for milking. Now, there is no problem with that.”

The tsetse fly is a bloodsucking insect that kills more than three million livestock in sub-Saharan Africa every year, costing the agriculture industry more than US $4 billion annually. The tsetse fly transmits parasites that cause a wasting disease called nagana in cattle. In some parts of Africa the fly also causes over 75 000 cases of human ‘sleeping sickness’, which affects the central nervous system, and causes disorientation, personality changes, slurred speech, seizures, difficulty walking and talking, and ultimately death.

Eradicating reproduction

Senegal has successfully integrated an insect birth control technique using irradiation to sterilize male flies, reducing the fly population over time (see box). The technique has suppressed the fly population by 98 per cent in two of the three areas in Niayes infested with tsetse, while the technique will be implemented in a third area next year, said Baba Sall, Project Manager at Senegal’s Ministry of Livestock and Animal Production. Eradicating the flies will significantly improve food security, and contribute to socio-economic progress, Sall said, adding that research on 227 farms has indicated that the income of the rural population in Niayes will increase by 30 per cent.

Life has become more comfortable not only for the animals, but also for the farmers, said Loulou Mendy, a pig farmer in the area. “Now, we can even sleep out in the open,” he said. “This was unthinkable before because of the tsetse bites.”

One of the 38 African countries infested with the tsetse fly, Senegal has a total infested area of around 60 000 km², Sall said. The operational phase of the campaign against the tsetse fly started in the Niayes region near the capital Dakar in 2011. Situated on the West Atlantic coast, made up of the remnants of Guinean forests, with the African oil palm as its main vegetation, Niayes has a coastal microclimate and ecological conditions that are favourable to the tsetse fly, Glossina palpalis gambiensis.

This region was selected by the Senegalese Government, as it is particularly suitable for breeds of cattle that produce more milk and meat than cattle in other areas. However, the high incidence of livestock infertility and weight loss, due to nagana, resulted in reduced meat and milk production, and cattle that were too frail to plough the land or transport produce, which in turn severely affected crop production, said Marc Vreysen, Head of the Insect Pest Control Laboratory at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

Previous eradication attempts

Prior eradication campaigns were carried out in the Niayes region from 1971 to 1981, leading to a decrease in tsetse flies for a
decade, said Sall, but the re-emergence of this pest in 2003 has had severe repercussions for livestock and farmers’ livelihoods since. Research revealed that previous eradication attempts were unsuccessful because the campaigns did not manage to reach the entire tsetse fly population in the area, leaving residual pockets from which the tsetse population could recover.

Sterilization using nuclear techniques is most effective under exactly these circumstances: when the fly population has been reduced significantly using conventional techniques but there are still pockets of insects left, Vreysen explained. “The sterilized male flies will seek out the virgin females wherever they are,” he said. “This will lead to complete elimination of the population in these areas.”

The project in Senegal started with a feasibility study initiated in 2006, supported by the IAEA, the Food and Agriculture Organization of the United Nations, the International Cooperation Centre of Agricultural Research for Development (CIRAD), and the Government of Senegal through the Senegalese Institute for Agricultural Research and the Directorate for Veterinary Services to assess the possibility of creating a tsetse-free zone in the Niayes region. This four-year study found that 28.7 per cent of cattle had devastating health problems due to the tsetse fly.

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The release of sterile male flies began in 2012, after a three-year period of pilot trials, training, preparation and testing.

**THE SCIENCE**

**Birth control for flies**

The sterile insect technique (SIT) is a form of pest control that uses ionizing radiation to sterilize male flies that are mass-produced in special rearing facilities. The sterile males are released systematically from the ground or by air in tsetse-infested areas, where they mate with wild females, which do not produce offspring. As a result, this technique can eventually eradicate populations of wild flies. The SIT is among the most environmentally friendly control tactics available, and is usually applied as the final component of an integrated campaign to remove insect populations.

The Joint FAO/IAEA Division supports about 40 SIT field projects delivered through the IAEA technical cooperation programme, like the one in Senegal, in different parts of Africa, Asia, Europe and Latin America. It has supported the successful eradication of the tsetse fly from the island of Unguja, Zanzibar; in Ethiopia it has reduced the fly population by 90 per cent in parts of the Southern Rift valley.
Sowing the seeds of change: plant mutation breeding helps Bangladesh to feed its growing population

By Nicole Jawerth

Villages in the northern region of Bangladesh used to struggle with poverty and hunger during the long months of the ‘monga’ periods, but they are now bustling as farmers and workers harvest new crop varieties developed using nuclear techniques.

“‘Monga’ is a Bengali word meaning ‘starvation,’” explained Mirza Mofazzal Islam, Principal Scientific Officer and Head of the Biotechnology Division at the Bangladesh Institute of Nuclear Agriculture (BINA). It is used to describe the time between mid-September and mid-November and from March to April, when “there is no work for the farm workers. They suffer; they are foodless,” said Mofazzal Islam.

Conventional rice crops take approximately 140 to 150 days to ripen, which results in long gaps between harvests, and increases the risks of crop damage due to diseases, hailstorms and drought, explained A. H. M. Razzaque, BINA’s Director General. A mutant rice variety produced by BINA with IAEA support using nuclear techniques (see box) has higher yields and shorter maturation periods of 110 to 120 days, allowing 30 to 35 extra days to grow other crops and vegetables.

With this variety, “farmers are now going for winter vegetables, pulses and oil seeds, then going again for another rice crop. So the whole period is occupied by crops, enhancing farming activity and increasing cropping intensity,” Razzaque said. This has increased the income of farmers, including women, and it has also contributed to Bangladesh’s approximately 26 per cent increase in rice production since 2003, Razzaque noted.

In the north-western part of Bangladesh, a region not affected by monga, new mutant varieties have also helped farmers facing harsh environmental conditions. “The livelihood of the farmers has changed with the new [mutant] varieties, especially mung bean and lentil varieties,” said Mohammad Faridul Islam, a farmer from the village Ishurdi. “Now I can fulfil the needs of my family; my two daughters are going to college. I can now buy better foods and clothes. Last year, I also bought farm land to increase my farm, as well as built my new house. My family no longer complains about their needs. They are happy.”

Coastal farmers are facing an entirely different problem, Razzaque said. More than one million hectares of land are affected by saline soil conditions and degradation and are unfit for cultivation using traditional crops. There are now two inbred varieties that are more saline-tolerant, and by replacing traditional varieties with BINA varieties, 40 to 50 per cent of these fallow lands can be cultivated, Razzaque explained. “But we need more saline-tolerant varieties in order to keep the land cultivated year-round,” he emphasized.

Preparing for climate change

Climate change is exacerbating the country’s environmental conditions, causing more saline water to enter normal soil, untimely rainfalls that lead to flooding and an increased number of areas with severe drought, said Razzaque.
“The government is pushing us to have good, sustainable mutant varieties to face the coming climate change issues,” said Mofazzal Islam. “That is why we are keenly aware of the importance of nuclear technology in developing such varieties so that we are prepared to combat the effects of the changing climate on agricultural development.”

With the IAEA’s support through training and fellowships, expert visits, human resources and laboratory development, and the provision of equipment since 1971, BINA has been able to develop new mutant crop varieties. The Institute has developed over 59 varieties using nuclear technology and 23 varieties of 12 different crop species using marker-assisted and other breeding techniques. With the many varieties, “we can address farmers’ needs and problems, and now hopefully the increasing demand,” Mofazzal Islam said.

“Once you fill your stomach, the question comes to quality,” Razzaque said. The demands are rising as farmers and the Government are becoming interested in different qualities and more nutritious crop varieties, fortified with zinc and iron, he said. “We have severe health problems in Bangladesh with zinc and iron deficiencies, particularly for lactating mothers and young kids. If they lack these micronutrients during pregnancy, after birth, they can suffer from other diseases and disabled children can be born.”

THE SCIENCE

Plant mutation breeding

Plant mutation breeding is the process of exposing plant seeds, cuttings or a shredded plant leaf to radiation, such as gamma rays, and then planting the seed or cultivating the irradiated material in a sterile rooting medium, which generates a plantlet. The individual plants are then multiplied and examined for their traits. Molecular marker-assisted breeding, often referred to as marker-assisted selection (MAS), is used to accelerate the selection of plants carrying genes of interest (desired traits). MAS involves using molecular markers for the selection of plants carrying certain genes that express desired traits. Those exhibiting the desired traits are further cultivated.

Plant mutation breeding does not involve gene modification, but rather uses a plant’s own genetic resources and mimics the natural process of spontaneous mutation, the motor of evolution, a process that otherwise takes hundreds of millions of years. By using radiation, scientists can significantly shorten the time it takes to see beneficial variations to as short as a year. Adequate screening techniques target certain traits to address key needs, such as plants tolerant to high salt levels in soil or resistant to certain pests. This makes it possible to validate a new variety for use in record time.

Looking ahead

BINA aims to continue collaborating with the IAEA. “We are expanding the horizon of our activities with the IAEA’s help,” said Razzaque. Now, in addition to plant mutation breeding, BINA is also working with the IAEA on soil and water management, pest control, and technology transfer to support farmers in Bangladesh and neighboring countries, he explained.

“Research is a continuous process. We cannot stop,” said Razzaque. “Our research strategy aims to satisfy the farmers with finer quality and nutritionally-enriched varieties, while facing the challenges prevailing in the fields and the climate. We will continue to develop new varieties and new technologies to fulfil the demand of the farmers and the demand of the country as a whole.”
Environment

Breathing easier: Indonesia works towards cleaner air

By Michael Amdi Madsen

Indonesians can look forward to breathing cleaner air following upcoming changes in regulations introduced as a result of a study conducted using nuclear analytical techniques. Lead pollution and other fine particulate matter in the air is now, for the first time, being accurately monitored and is giving Indonesian officials a good understanding of their air pollution problem and how to manage it.

“In the next three to five years, we’ll be covering 34 cities, and accomplish our goal of monitoring the capitals of all of Indonesia’s provinces.”

— Muhayatun Santoso, senior researcher, National Nuclear Energy Agency (BATAN), Indonesia

This was not always the case. In 2006 Indonesia launched an urban air quality improvement project, aimed at having clean and healthy urban air in Indonesia in 2020. The country introduced a monitoring system that utilized a variety of conventional techniques, including air quality management systems in ten cities and passive samplers in 33 provinces.

“Due to limited resources, the air quality management systems couldn’t operate effectively in all ten cities — maintaining the system cost a lot of money,” Santoso said. “The system itself had limits too, and could not monitor particulate matter smaller than 2.5 micrometres, meaning it wasn’t detecting a range of potentially harmful air pollutants.

We needed to improve the system and try something different.”

Trying something new

Trying something different meant working with the IAEA to include nuclear analytical techniques in the air quality monitoring project. Neutron activation analysis, X-ray fluorescence and ion beam analysis can produce large sets of unique data about the elemental compositions of airborne particulate matter — key information in determining possible sources of air pollution (see box).

“Lead pollution from human sources is mainly fine particulate matter — less than 2.5 micrometres — and detecting these sources can be difficult,” Santoso said. Using proton induced X-ray emission analysis and knowledge obtained from the IAEA, the BATAN research team managed to trace the cause and source of the lead pollution in various areas, including in Serpong, near Jakarta. “We were able to associate a high percentage of the pollution to a lead battery recycling centre and production facility,” she said.

Results from the project have been used to help law enforcement crackdown on legal and illegal polluters and educate the public about the dangers of lead pollution, Santoso said.

Collaborating with local cities, provincial environment protection agencies and Indonesia’s Ministry of Environment, BATAN expanded the extent of the monitoring beyond Java. “We made a big step in expanding sampling locations from one site in Bandung, to 16 cities covering our biggest islands,” she said.

A promising commitment

The air monitoring results are encouraging change at the legislative level. Outcomes from the lead pollution study have brought revisions to Indonesia’s law on air pollution control — lowering the threshold of

Air sampling in Palangka Raya, Borneo, Indonesia.
(Photo: M. Santoso/BATAN)
acceptable lead concentrations in ambient air. “This contribution has showed a promising improvement of government commitment, policy and strategy to combat air pollution on a national scale,” Santoso said. The project is on track to expand further, using more techniques at more sites, she said. “In the next three to five years, we’ll be covering 34 cities, and accomplish our goal of monitoring the capitals of all of Indonesia’s provinces.”

Monitoring development

Indonesia is rapidly developing and has plans to build more than 30 power plants in Java and Bali, including a 10 000 megawatt coal plant. These plants will be contributors to environmental pollution, requiring further monitoring, Santoso explained. New analytical characterization studies on coal feed, its combustion products and their impact on the environment will need to be pursued by the air pollution monitoring project, she said.

Assessing the environmental and physiological impact of toxic elements depends on exposure levels, quantities and chemical specificity. “Making elemental and chemical state analyses of arsenic, mercury, cadmium, nickel, chromium and lead — toxic trace elements associated with coal burning — is crucial to us, but those elements are unfortunately below the detection limits of energy dispersive X-ray fluorescence and particle-induced X-ray emission, the nuclear technologies we’ve been using,” she said.

To overcome this limitation, Indonesia needs access to a synchrotron — a type of particle accelerator — that can help them analyse their samples. The IAEA is helping Indonesia analyse its samples using a synchrotron made available to the Agency through a coordinated research project with partner organizations in Trieste, Italy. BATAN hopes that this cooperation will give the air quality monitoring project more significant information about the speciation and chemical composition of their air pollutants, helping them to better evaluate its environmental impact and assure everyone a fresh breath of air.

Air pollution is a regional problem, Gashaw Gebeyehu Wolde, an IAEA programme officer explained. “Transboundary pollution is a serious concern, and by supporting training and by providing expertise, we help countries establish sampling mechanisms that can pinpoint the cause and source of air pollution,” he said. “It’s important to know whether pollution comes from a human source, or whether it is a result of a forest fire or volcano.” Through its regional programme, the IAEA assists countries throughout South East Asia with the development of a comprehensive regional database for shared use, and supports them in developing analysis capabilities locally, and, when necessary, provides avenues for samples to be analysed in regional resource centres that have more sophisticated analysis facilities, like those in Australia and New Zealand.

THE SCIENCE

Particle-induced X-ray emission

Particle-induced X-ray emission (PIXE) is a nuclear analytical technique that uses an ion beam — a beam of charged particles — to determine information about the elemental make-up of a sample.

PIXE works by exposing a sample to an ion beam. The interaction between the beam and the sample gives off electromagnetic radiation whose wavelength can be attributed to specific elements and isotopes. This can tell a scientist not only what a sample is, but also its origin.

The use of PIXE is not limited to air pollution monitoring; since it is a non-destructive analysis technique — it does not destroy the sample it is studying — PIXE can be applied in archaeology and art conservation.
Fishing for answers: Sri Lanka proves radioactivity is not an issue in its coastal waters

By Michael Amdi Madsen

Over one million Sri Lankans rely on the sea for their income, and about half of the animal protein intake of the island’s population comes from fish. The sea provides the inhabitants of the country with livelihoods, day-to-day nutrition, or both. Concerns after the 11 March 2011 Fukushima Daiichi nuclear power plant accident have highlighted the importance of monitoring radioactive substances in the oceans. But Sri Lanka had neither the equipment nor the expertise to measure radioactivity levels in its waters.

Sri Lankans were particularly concerned about the quality of the fish they were eating. “We were compelled to monitor the radioactivity of fish samples collected from the local catch, from the imported frozen fish, and from the canned fish imported from other countries,” says Vajira Waduge, Director of the Life Science Division of Sri Lanka’s Atomic Energy Board (AEB).

The IAEA launched a project to help 24 countries in the region to establish benchmarks for radioactivity levels, natural as well as artificial, in their coastal waters (see box).

Waduge and his team detected caesium-137 in samples of imported canned fish, but only in insignificant levels. Low levels of caesium have been consistently detected in Sri Lankan waters and sediment, but only as a result of nuclear weapon testing fallout from the 1950s and 1960s. To help get the message across to the public that their seafood was safe, the fishing industry, importers, and the AEB launched an advertising campaign through awareness programmes, Waduge said.

Getting the tools

Prior to the start of the project, the AEB had basic gamma spectrometry analysis capabilities, but it could not carry out any marine sample analysis, which is necessary for establishing a database on marine radioactivity.

Through IAEA workshops and training the AEB established sampling methodologies and analytical procedures — allowing it to monitor existing radioactivity levels in seabed sediments, seawater, sea fish and seaweeds.

Subsequently, the AEB was able to secure funds from the government to procure new, more sophisticated equipment — enabling its staff to pick up very slight traces of radionuclides and establish benchmark data. “The instrument has been of great help in sample analysis because of its high capacity,” said Waduge. Collaboration with the Marine Environment Protection Authority has been one of the key points in the success of the project in Sri Lanka, he added.
Last December the AEB was also able to acquire equipment to analyse samples for the baseline data for strontium-90 — a product of nuclear fission in nuclear power plants and in fallout from nuclear weapons testing — and is looking to the IAEA for assistance and training to make the best use of the new equipment, Waduge said.

Sri Lanka was not the only country without baseline data on marine radioactivity. Throughout Asia and the Pacific, many countries lacked the skills, equipment or the money to regularly measure marine radioactivity. To meet their needs, the IAEA set up a project helping 24 countries to develop marine monitoring capabilities, with a focus on detecting caesium. “Different countries have different capabilities to monitor marine radioactivity,” said Iolanda Osvath, Head of the IAEA’s Radiometrics Laboratory. “When we started this project, there were some small island States where we had to start from scratch, while in the case of others we assisted to improve their capacity or refine their methods.”

The next step
In Sri Lanka the project has convinced policymakers of the necessity of having a monitoring programme and has secured sufficient funds for infrastructure development. A new laboratory complex, to be completed by 2016, has dedicated laboratories for gamma spectrometry, alpha and beta spectrometry and radiochemistry. Sri Lanka now has an established database of baseline data on its waters, something it hopes to maintain and expand upon with the addition of further data. “The next step is to extend our sampling plan to deep waters in the Mannar Basin to establish benchmark values there,” Waduge said. The collected benchmark data will be added to the IAEA’s Marine Information System database and the Asia-Pacific Marine Radioactivity Database, so that other countries can easily access it.

THE SCIENCE

What is a benchmark?
Detecting trace amounts of radionuclides in a sample is difficult and requires very specialized and sensitive equipment. In order for radiation monitoring authorities to quickly know whether detected radiation is of a new source or not, they need baseline data — a ‘benchmark’.

A benchmark is the foundation data of a database that assists in future monitoring. If a new sample contains a radionuclide it can be compared against the benchmark to see if it is of new origin.

Most of the ocean has very low levels of radionuclides — usually from the fallout of historic nuclear weapons testing. When radionuclides are detected, being able to compare them to previously sampled data can reveal whether the contamination is old or new.
Water

Bountiful crop with every drop: using drip irrigation to increase yields and conserve water

By Rodolfo Quevenco

Cauliflower, broccoli, sweet pepper and many other nutritious vegetables used to be expensive in Mauritius. The island’s climate and traditional agricultural practices were not suitable for cultivating several high value vegetable crops, while importing them to the island state was prohibitively costly due to the long distances involved.

This has all changed over the past few years, and local farms are now starting to supply the country’s growing population and burgeoning tourism industry with fresh, locally grown produce.

The trick: drip irrigation, which was made possible with the help of nuclear techniques that can measure moisture levels in both the soil and the plants, enabling farmers and agricultural officers to work out exactly how much water and nutrients to use and when (see box).

“The adoption of drip irrigation has increased food crop production and the revenues of farmers across the island,” said Ram Vencatasamy, the research scientist in charge of the irrigation programme at the Mauritian Food and Agricultural Research and Extension Institute (FAREI).

“Drip irrigation is a very good system for us small-scale farmers,” said Manoj Chumroo, a farmer from eastern Mauritius, who has been growing vegetables with his wife on their 1200-acre plot since 1986. “It can really help increase our yield and income.”

Drip irrigation allows water to be fed to the plants through a network of pipes or narrow tubes that deliver water directly to either the base or the root. The process helps to reduce water use.

“I doubled my crop yield this season,” Chumroo said. “And the vegetable auctioneers have paid good market prices because of the premium quality of the cauliflower and chilli.”

As a result, Chumroo has replaced his bicycle with a motorcycle for his morning drive to the fields. He has bought an adjacent plot of land and has taken out a bank loan to introduce drip irrigation there as well. He has also completed the construction of his house and has bought additional furniture. “Once in a while, I can even take my family to dinner out in a restaurant,” he said.

Almost 80 per cent of the total cultivated area in Mauritius is rain-fed. With limited financial resources to invest in expensive sprinkler systems or irrigation dams, farmers like Chumroo used to carry water in cans, a process that is both labour-intensive and wasteful. To make matters worse, said Vencatasamy, there has been a noticeable decrease in annual rainfall in Mauritius over the past 10 years, lowering crop yield and the productivity of small-scale farmers.

Agriculture already accounts for 70 per cent of global freshwater use. By 2050, global water requirements for agriculture are expected to grow another 50 per cent to meet...
demands of a growing population, according to the Food and Agriculture Organization of the United Nations (FAO). Improving water efficiency is crucial for sustainable development.

“Fertigation”: Water-fertilizer combo

To further optimize crop yields, and conserve resources, farmers increasingly apply a technique that provides the plants with fertilizers mixed with water, a process known as fertigation. Fertilizer using an isotope of nitrogen is applied to a small plot of land through fertigation to determine the efficiency of fertilizer and water uptake by the plants and to optimize the amounts required, explained Lee Kheng Heng, Head of the Soil and Water Management and Crop Nutrition Section at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. The technique can save up to half of the fertilizer traditionally used to achieve the same results, she said.

“Scaling back on fertilizer helps to protect people and the environment against pollution as there is less chance of residual fertilizer seeping into the groundwater or polluting nearby streams and rivers,” Heng said. The IAEA has made the technique available to agriculture officers and farmers participating in 19 drip irrigation projects across Africa.

Results include:

1. **Kenya**: Development of a low-cost, small-scale drip irrigation system that generated 2.8 times the yield of field grown tomatoes while using only 45% of the water traditionally applied by hand.

2. **Tanzania**: The use of drip irrigation provided a tea yield four times higher than that of the rain-fed, non-irrigated tea.

3. **Sudan**: Drip irrigation saved irrigation water by 60% and increased the yield of onions by 40% compared to surface irrigation. The system is now adopted by farmers in many villages north and south of Kassala in eastern Sudan.

THE SCIENCE

**Nitrogen isotopes in soil management**

Isotopic and nuclear techniques play an important and unique role in assessing the status and movement of water in soil. This is essential to developing strategies for sustainable water management in agriculture and for the successful use of cheaper, more effective irrigation alternatives like drip irrigation.

Nitrogen fertilizers played a crucial role in increasing crop productivity to alleviate food insecurity. However, nitrogen fertilizers are expensive in many countries. In addition, many agricultural crops use nitrogen inefficiently — leaving over 50% of it in the ground.

Fertigation is used to determine where the fertilizer goes once it is applied to the soil in order to figure out how efficiently plants utilize nutrients from fertilizer. Scientists use fertilizer labelled with the stable nitrogen isotope nitrogen-15 in a small plot on an experimental station or on a farmer’s field. The nitrogen-15 isotopes have a different molecular weight from the rest of the fertilizer mixture, allowing scientists to follow them as they get into the soil and the plant. Based on this, they can determine the amount of fertilizer to use and the best method for applying it. This ideal recipe is then transferred to the farmers.
Out of sight, but in their minds: Brazil and its neighbours work together to protect one of the world’s largest groundwater reservoirs

By Nicole Jawerth

Shrouded in mystery, the future of the largest groundwater reservoir in Latin America once left scientists, academics and politicians in Brazil, Argentina, Paraguay and Uruguay concerned about the fate of their major freshwater resource. Uncovering clues using nuclear techniques, Brazil and its neighbours are now well-acquainted with the Guarani Aquifer and can confidently expect that, with their new protection and sustainable use framework, water from the aquifer will continue to flow for at least another 200 years.

Using isotope hydrology, a nuclear technique (see box), the four countries analysed and assessed the aquifer to evaluate the age, origin and evolution of the groundwater, as well as its quality and the risk of contamination. “The studies were an important contribution to the project because they generated an integrated picture of the whole aquifer, which helped to interpret many important geological, hydrochemical and hydrogeological findings,” said Hung Kiang Chang, Professor at the Institute of Geosciences and Exact Sciences (IGCE) at the São Paulo State University.

Hidden under lush green fertile lands, the aquifer spans over 1.2 million square kilometres — three times the size of the Caspian Sea. With stores of over 37 000 cubic kilometres of fresh water in its sandstone pores and fissures dating back to around 200 to 130 million years ago, it is a source of drinking water, and it supplies industry, agricultural irrigation and thermal spa tourism for the region.

“It is an incredible transboundary groundwater resource that has been around for hundreds of thousands of years,” said Chang. “The aquifer influences the lives of millions of people. If it were no longer available, the impact would be enormous.”

The aquifer is particularly important for Brazil, as the country consumes around 90 per cent of the one billion cubic metres of total water extracted per year, with 14 million people relying on it, Chang added.

The impact of civilization

Though much of the aquifer remains intact, civilization has taken its toll on the water reserve. “Nature has blessed the region with an abundant supply of water, but it is not enough to endlessly indulge all the needs of modern society,” said Chang. “Water consumption is rising and the population is expanding, and in some areas, uncontrolled pollution and unregulated water use can pose a threat,” he explained. “Climate change will also strongly affect the rainfall and evapotranspiration in the aquifer recharge areas,” he noted.

The consequences of overexploitation and pollution compromise local water supplies due to poor sanitary conditions, which, in the medium term, could lead to ecological imbalance from, for example, bacterial growths in wells that are improperly regulated during drilling, said Gerôncio Rocha, who recently retired as the coordinator of the São Paulo State Preparation Unit for the Guarani Aquifer Project.
Until recently, the four countries had lacked the information they needed to know how civilization impacts the aquifer and how to best protect and sustainably use it. Therefore, they jointly developed the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System, also known as the Guarani Project.

“The main motivation behind the project was of a technical nature,” said Rocha. It raises questions about the aquifer’s water flows and the amount of renewable water, how pollution or contamination affects it, where the areas of recharge and discharge are, and its age and chemical composition, Rocha said. In addition to discussions about unregulated exploitation of the groundwater, “these and other questions were the basis of the concerns,” said Rocha.

With support from several international organizations, including the IAEA, the project was designed to use scientific and technical studies to understand the aquifer and what measures were necessary to protect and sustainably use it. The countries developed policies for the aquifer’s protection and sustainable management that also took into account institutional, legal, economic and environmental dimensions.

**Dating the water’s age**

The Guarani Aquifer Project took place from 2003 to 2009, and the resulting Strategic Action Plan was released in 2011. Though the project led to comprehensive databases of information about the aquifer, “there is still more work needed to provide additional information about the aquifer and its hydrological characteristics,” said Luis Araguás-Araguás, isotope hydrologist at the IAEA.

There have since been several follow-up projects undertaken by the four countries, among which is an ongoing IAEA follow-up project with Brazil and Argentina to further study the aquifer’s age using isotope hydrology. The project has so far revealed that the groundwater in the central portions of the aquifer is up to 800,000 years old.

Historically, water management in the region has primarily focused on surface water, despite the significant role of groundwater sources. “Today, after the project, there is greater public awareness of the actual and potential threats to the aquifer,” Rocha said. “The population’s perception of the aquifer’s importance is essential for its successful management.”

**THE SCIENCE**

**Isotope hydrology**

Water molecules carry unique fingerprints based on their different proportions of isotopes, which are chemical elements with atoms that have the same number of protons, but a different number of neutrons in the nucleus. They may be natural or artificial. Radioisotopes are unstable and are constantly releasing energy called radioactivity as they decay to regain stability. Scientists can measure the period of time it takes for half of the radioisotopes to decay, known as its half-life. By knowing the half-life of a radioisotope and the isotope content in water or in other substances, scientists can determine the age of rocks and water that contain those radioisotopes.

Stable isotopes do not disintegrate and remain constant throughout the entire period they are present in water. Scientists use the different isotope contents in surface and groundwater to determine various factors and processes, including sources and history of water, past and present rainfall conditions, recharge of aquifers, mixing and interactions of water bodies, evaporation processes, geothermal resources, and pollution processes.
The stage is set for uranium mining in the United Republic of Tanzania, following recent changes to the country’s regulatory framework that brought it in line with IAEA recommendations. Environmental considerations and the involvement of the local community in monitoring the licencing process and future operations will contribute to the sustainability of the project, said Tanzanian officials and IAEA experts.

Tanzania, which has identified uranium resources of about 60,000 tonnes, looks to begin mining in 2016 in order to exploit its uranium deposits as part of the country’s plans to increase the contribution of the mining sector from 3.3% of the gross domestic product in 2013 to 10% by the end of the decade. With its gold and diamond reserves nearing depletion, the country is shifting its focus to uranium. “Now it is time for the country to benefit from its uranium deposits,” said Iddi Mkilaha, Director General of the Tanzania Atomic Energy Commission.

Following preliminary analysis, the government has identified half a dozen sites with good potential for mining and has issued prospector licenses. Recent feasibility studies identified one site with early commercial potential, Mkilaha said, but given the subsequent fall in uranium prices and the ongoing negotiations with foreign mining companies, no mining work has begun so far.

The government has requested IAEA assistance to bring its relevant legislation and procedures in line with safety and environmental standards and to make sure that good practices are applied ahead of the commencement of mining operations, Mkilaha said. “We wanted the Tanzanian people to benefit and realized that we did not have the proper legislation in place to ensure safe mining, processing and transportation. Now we do,” he said.

The review considered regulatory, health, safety and environmental aspects, as well as sustainability in operations. The team provided several suggestions related to the regulatory framework, and to ensure that the mining activities followed IAEA standards and international good practices, especially related to health, safety and environmental issues, explained Harikrishnan Tulsidas, the nuclear technology specialist at the IAEA heading the Tanzania project.

**Holistic approach**

Thanks to the IAEA’s input, the government took a more holistic approach to the issue of uranium mining and introduced environmental regulations, particularly in the area of water protection, Mkilaha said. “We had not before realized the importance of monitoring water streams and groundwater around the future mining areas,” he said, adding that in the wake of the IAEA project baseline...
measurements took place to establish levels of different minerals and chemicals in the water. “We will be able to monitor the activity in comparison to these values,” he said.

Tanzanian experts and policymakers also learned about the importance of getting the buy-in of the local community ahead of time, Mkilaha said. “We realized that with community involvement, we could reduce potential resistance to the project.”

The authorities have engaged the local population through a series of meetings, including on employment opportunities, Mkilaha said. The research team conducting uranium exploration “has already employed local people, and the community sees the project as an economic opportunity in the area,” he said. Following the recommendations from the IAEA, the government will, in consultation with the community leaders, create an environmental monitoring plan and set up a community consultation committee, chaired by a local representative, for ongoing monitoring of the operations, particularly in terms of environmental sustainability.

The review also called for a clear separation of responsibilities within the government, so that its role as a regulator is not compromised through its involvement as a strategic partner. “There was a possible risk and conflict of interest in the original set-up,” Tulsidas said. As a result of the recommendations, the regulatory function of the Ministry of Communication, Science and Technology has been strengthened, with dedicated functional units responsible for oversight created at both the Ministry of Communication, Science and Technology and the Ministry of Energy and Minerals.

A second life for mining waste
IAEA experts also helped Tanzania devise plans to extract uranium from tailings, or mine dumps, left over from gold and phosphate mining. “This was considered waste before, but now we will see how they can be put to potential economic use,” Tulsidas said.

With the price of uranium recovering and negotiations with investors progressing, the first mine will likely become operational in 2016 in the Mkuju River area, around 470 kilometres southwest of the capital Dar es Salaam, Mkilaha said.

Hugo Cohen Albertini also contributed to this article.

THE SCIENCE

Uranium mining
Like other minerals, uranium is typically mined using open-pit technology when the ore is close to the surface, and underground mining when it is deeper down. Underground mining requires a high level of ventilation to lower the exposure of workers to radon gas. Radon is produced during the natural decay process of uranium.

The ore typically contains from around a few hundred parts per million to up to 20 per cent uranium. From conventional mines, ore is transported to treatment plants or mills where uranium oxides are separated from the ore. When the geology allows, chemicals can be pumped into the ground to dissolve the uranium in what is called in-situ recovery operations. By injecting weakly alkaline solutions, such as those made with baking soda, or alternatively acidic solutions into the ore through pipes, miners separate uranium from the ore and pump the resulting solution back to the surface to recover the uranium.

Globally, close to 60 000 tonnes of uranium are produced annually. Kazakhstan, Canada and Australia are the top three producers and together account for close to two thirds of world uranium production (see chart).

Uranium Production in 2012: 58 816 tonnes of uranium

Source: IAEA

Technology and the Ministry of Energy and Minerals.
Towards safe and secure use of nuclear energy in Turkey

By Adem Mutluer

"As it develops its nuclear power programme, Turkey is committed to moving forward in a safe, secure and safeguarded way."

— Emine Birnur Fertekligil, Turkey's Representative to the IAEA

Energy

Nuclear power will play a key role in Turkey’s future energy strategy as the country moves toward achieving supply security while also meeting the challenge of limiting emissions that contribute to climate change.

Every year demand for electricity in Turkey’s bustling economy is growing by more than five per cent, yet the country depends on imported resources to meet 73 per cent of its current energy needs. Turkey’s new nuclear power programme aims to provide at least 10 per cent of the country’s energy by 2023, according to Turkey’s Ministry of Energy and Natural Resources.

The energy strategy includes two nuclear power plants with a total of eight reactor units to be in operation by 2028, and a third plant to be under construction by 2023, said Emine Birnur Fertekligil, Turkey’s Representative to the IAEA. “The peaceful applications of nuclear technology are very important, not only in the energy field but also in other areas of sustainable development.”

Taking the required steps

Turkey has turned to the IAEA for advice on and assistance with taking the steps required for developing a safe nuclear energy programme, Fertekligil said. “As it develops its nuclear power programme, Turkey is committed to moving forward in a safe, secure and safeguarded way,” she said.

In 2013, an IAEA Integrated Nuclear Infrastructure Review (INIR) provided a team of international experts to help Turkey assess its readiness for developing a nuclear power programme. The mission involved 25 Turkish institutions and provided recommendations and suggestions, and identified several good practices.

“The 2013 INIR mission provided insightful recommendations that Turkey used to develop a national action plan,” said Necati Yamaç, Head, Department of Nuclear Energy Project Implementation, Ministry of Energy and Natural Resources. “Amending or drafting new laws requires a huge amount of preparation, and in the case of Turkey, it has taken around two years. The INIR mission sparked discussions between various ministries and helped us identify new approaches and concepts,” he said.

INIR missions are designed to help IAEA Member States measure how far they have progressed towards meeting the requirements for a safe and secure nuclear power programme. They review all facets of a nuclear power programme, from the establishment of a regulatory body, and other legal requirements, to the utility operating the power plant, and the relevant Government stakeholders involved.

A look in the mirror

One of the benefits of an INIR mission is an initial self-evaluation the country undertakes before the mission begins.

Self-evaluation is a useful process because it involves interactions and discussions among the organizations involved in infrastructure development, said Anne Starz, Acting Head of the Nuclear Infrastructure Development Section at the IAEA. For Turkey, there were 25 organizations involved, she added.
The road toward a nuclear power programme

Turkey’s path to its first nuclear power plant has four previous plans to introduce nuclear power in its wake. The first was in the late 1970s, when a site at Akkuyu on the eastern Mediterranean coast was licensed, and the last in 2008 when Turkey issued a request for bids.

In 2010, Turkey and the Russian Federation signed an agreement for the construction and operation of a nuclear power plant at the Akkuyu site, and three years later, an intergovernmental agreement with Japan was signed to develop a second nuclear power plant project at the Sinop site on the Black Sea.

Most recently, in addition to the INIR mission, Turkey’s draft nuclear energy laws have also been reviewed by the IAEA. Turkey’s nuclear law addresses safety, security and safeguards. A separate law for civil liability for nuclear damage was submitted to the IAEA for review in August 2014.

As Turkey goes further down the road toward a nuclear power programme, it has sought to learn from other countries. Through organizing several technical visits to other countries that are using nuclear energy, Turkey can gain a better understanding of as well as solutions for challenges faced in the area of nuclear technology, said Yamaç. “Looking at the experience of other countries is a good way for us to learn,” he said.

Peter Rickwood also contributed to this article.

THE SCIENCE

Nuclear power plant

A nuclear power plant generates electricity using heat from a controlled chain of nuclear reactions — a process whereby a single nuclear reaction spurs a series of subsequent nuclear reactions that result in large amounts of energy being released. The reactions occur inside the nuclear reactor, which is a device that is designed to initiate and control a sustained nuclear chain reaction. There are many types of nuclear reactors. Each has different designs and uses different mechanisms, water or gas, to generate power.

The reactor type to be used in Turkey’s power plant at the Akkuyu site is a water cooled water moderated power reactor (WWER). This reactor type uses heat produced from the nuclear chain reaction to heat water circulating through a separate compartment inside the reactor. Once heated, the reactor-heated water is pressurized and then pumped through hundreds or thousands of tubes in a steam generator, where the reactor-heated water heats an adjacent compartment containing water. This causes the adjacent water to boil and produce steam. The reactor-heated water returns to its compartment in the reactor to cycle through the process again, while the steam is delivered to steam-powered turbines that drive electrical generators connected to an electric grid designed for electricity distribution. After passing through the turbine, the steam is cooled down and converted back to liquid inside a condenser to be sent through the process again. The electricity produced through this process is known as nuclear power.
Better safe than sorry: increasing safety in radioactive waste management

By Miklos Gaspar

Abderrahim Bouih used to be worried about space. In charge of managing Morocco’s radioactive waste since 2006, he had long projected that the country’s sole radioactive waste facility would fill up by 2019. Thanks to a new methodology he and his colleagues learned through an IAEA project, they can now dismantle smoke detectors, lightning rods and other waste that contains radioactive material, safely separating the radioactive components from the metal, and significantly reducing the amount of radioactive waste they need to store.

“We have condensed 60 drums of waste into just two,” said Bouih, Head of the Radioactive Waste Collection, Treatment and Storage Unit at the Moroccan National Centre for Nuclear Energy, Sciences and Technology. “This means our site won’t fill up for another 16 years.”

Morocco has thousands of items containing low level radioactive waste. Bouih and his colleagues regularly get calls from local authorities and companies from across the country to pick up their waste. “Next week we are going to an old hotel to collect 200 smoke detectors,” he said. Older generation smoke detectors and lightning rods often have a small radioactive source as an active component of the device.

Back to France for processing

As another outcome of its work with the IAEA, Morocco for the first time ever sent three old radiotherapy machines used for medical imaging back to France for processing last year. “Being able to provide a safe solution for our radioactive waste was a major step for us,” Bouih said. The radioactive components used in radiotherapy machines are generally more hazardous to human health and the environment, and may also be more vulnerable to theft or misuse if they are not managed securely, than the majority of the more benign sources used in industrial applications and research.

Morocco, like most other countries without a nuclear industry, is not appropriately equipped to manage waste with high levels of radioactivity. The IAEA arranged, oversaw and supervised the repatriation process.

Safe storage of radioactive sources in Montenegro

In Montenegro, another country that participated in the project, IAEA experts and local officials dealt with 98 of the...
country’s radioactive sources in a joint exercise last year. This allowed the staff of the Centre for Ecotoxicological Research of Montenegro to learn the technique to disassemble radioactive sources and place them in safe storage through a process known as conditioning, said Tamara Djurovic, Head of the Department for Radiation, Air and Noise Protection at Montenegro’s Ministry of Sustainable Development and Tourism.

Most of the radioactive waste Montenegro needs to deal with comes from military use, she explained. The country, for instance, has over 7000 military compasses to dismantle, she said. These contain radium, and the Centre is waiting for a final government decision before beginning the work to condition them. “Even while waiting for their go-ahead, we have been able to repackage our sources and prevent the release of radon,” she said. “The sources are now safe in stainless steel barrels.”

The country has also approved a new policy on the safe handling of radioactive materials, following an IAEA course for policymakers on the subject. “After the course, we were able to realign our strategy and policymaking in managing these sources,” she said.

Harmonizing policies across the Mediterranean region

Both Morocco and Montenegro are participating in an interregional project from 2012 to 2015 to help countries from the Mediterranean region establish adequate and permanent control over their radioactive sources. The project supported a harmonized approach consistent with IAEA safety standards and other international best practices. It aimed to define and establish coordinated policies and approaches to the control and movement of radioactive sources and has also contributed to reinforcing regulatory and management capabilities. Furthermore, the project has fostered cooperation among the countries of the region to address matters of common concern regarding the use of the Mediterranean Sea as a transport channel for radioactive substances.

Adem Mutluer also contributed to this article.

THE SCIENCE
Source conditioning

Conditioning is the first major step in the waste management of radioactive sources, which are man-made radioactive materials used in industry, medicine, agriculture and research. It results in a package suitable for handling, storage, transport or disposal of the material.

The simplest technique manages the source without removing it from its original device or shield, by placing the device holding the source into concrete. This operation can be made ‘irretrievable’ or ‘retrievable’ depending on whether it is for temporary or final storage.

When a more elaborate technique is used, the source is removed from its original device and the bare source is re-encapsulated — possibly together with other sources — in a new stainless steel capsule designed for this purpose. The capsule is usually placed in a special waste container.

In Morocco
60 drums of low level radioactive waste now fits into just 2 drums

60 drums of low level radioactive waste now fits into just 2 drums.

Verifying the radioactivity level of a capsule containing conditioned caesium-137 sources. (Photo: J. Balla/IAEA)
Making the world more secure, one research reactor at a time

By Adem Mutluer

During the night of 29 September 2014, a heavy transport plane took off from an air base in Kazakhstan after an operation to remove fuel and increase the security of a research reactor.

In its cargo bay sat four massive containers, provided by the IAEA, that had been filled with a total of 10.2 kilograms of highly enriched uranium (HEU), on its way to be diluted to a safe substance or securely stored at the flight’s destination in Russia.

The Alatau 6 megawatt light water reactor is used for a number of purposes, including scientific research, isotope production for medicine, and testing material for use in industry. For example, the reactor produces molybdenum-99, an important medical radioisotope used in 70% of nuclear medicine procedures worldwide, and relied on for tens of millions of medical procedures a year (see related article, page 12).

Before the implementation of the conversion to LEU began, scientists at the reactor performed post-irradiation studies of LEU fuel to determine the suitability of the reactor for conversion to LEU. The IAEA provided the equipment for this research, Chakrov explained. By analysing specimens irradiated to different doses of radiation, modelling the conditions under which the LEU would be used in the reactor after the conversion, scientists confirmed that the reactor was suitable for using LEU in a safe and manageable way, he said.

“The procurement of this equipment by the IAEA was absolutely necessary for
the project to take place and to give us the confidence to move forward,” Chakrov said.

Step-by-step removal

The containers of fuel on the plane in September represent one of several batches of fuel to be repatriated from Alatau. In July 2015, the reactor will be temporarily turned off to allow for a cooling off period of six months. During this time, the reactor’s instrumentation and control system will be replaced in advance of the switch in fuel. In January 2016, the reactor will restart, using LEU.

“Because of the risks HEU poses, more than 2150 kilograms of HEU, supplied by the former Soviet Union, has been repatriated to the Russian Federation in 60 shipments from 14 countries under the Tripartite Initiative between Russia, the United States and the IAEA, often called the Russian Research Reactor Fuel Return (RRRFR) Programme (see chart),” said Sandor Tozser, a nuclear engineer at the IAEA’s Research Reactor Section. The IAEA acts as an administrator and provides technical knowledge and equipment, he explained. The repatriation of HEU fuel from the Alatau reactor is part of this programme.

Peter Rickwood also contributed to this article.

THE SCIENCE

Uranium enrichment

Highly enriched uranium has historically been used in research reactors for scientific purposes. Uranium is a naturally occurring element, and uranium-235 ($^{235}$U) and uranium-238 ($^{238}$U) are isotopes of uranium, meaning they share the same number of protons as uranium, but have a different number of neutrons. When uranium is mined from the ground, the mass contains only 0.7% $^{235}$U, the fissionable element, and 99.3% $^{238}$U, which is stable and does not undergo nuclear reactions. Enriching uranium means increasing the percentage of $^{235}$U in the mass. Nuclear power plants in operation around the world typically use uranium enriched to between 4% and 7%.

Enriching can be done in several ways, each using a method called isotope separation. Isotope separation is the process of concentrating specific isotopes of a chemical element by removing other isotopes. In this case, isotope separation is used to increase the concentration of $^{235}$U in a mass of uranium. The most common and effective method for doing this is by using a centrifuge, a specialized device that puts an object in rotation around a fixed axis, taking advantage of the difference in atomic mass between $^{238}$U and $^{235}$U. When centrifuges spin, they separate $^{235}$U from $^{238}$U, allowing $^{235}$U to be further concentrated, or enriched, for use. The enrichment process can be done to create different levels of enriched $^{235}$U; however, it is not an easy process and requires time, expertise and expense. Uranium enriched to contain over 20% of $^{235}$U is considered HEU.
Protecting Romania’s cultural heritage using nuclear technology

By Aabha Dixit

Preserving art and cultural heritage is a shared ambition of the global community. The past plays an important role in understanding a people’s way of life, which is why Father Ioan from an Orthodox church in the village of Izvoarele on the southern slopes of the Carpathian mountains in Romania was desperate to save the revered 19th century assembly of icons of his parish. Faced with a dreadful situation when he noticed insects inside his church, Father Ioan turned for help to a very unlikely source — radiation treatment — to prevent any further parasite attacks.

Woodworms were nibbling away at the sacred work of art, known as an iconostasis, in this old church in the picturesque hamlet of 800 homes, 120 kilometres north of Bucharest. “It was my responsibility to take action. At the beginning, I started to inject chemical solutions in the insect holes. Because the icons are thick objects, the injection solution did not penetrate deep to the source of the worm attack and there was no effect. That is why I considered a better solution,” said Father Ioan.

He took the insect-infested iconostasis to the IRASM Radiation Processing Centre in Bucharest, where staff welcomed him with awe. “He heard about us on television. He arrived alone at our door, with no phone call in advance,” said Valentin Moise, Director of the Centre, which is part of the Horia Hulubei National Institute of Physics and Nuclear Engineering.

The traditional approach to eradicate insects, such as woodworm, is to inject poison either in the form of a gas or liquid into each hole created by the insect and seal it with wax. The poison should reach the area in which the insect subsists and multiplies; however, the insects are often not fully eradicated. Chemical treatment is a long and expensive process that also exposes people to hazardous fumes. In comparison, radiation treatment requires a shorter treatment time, is inexpensive and completely eliminates the insects.

Romania is among the 18 IAEA Member States that have received support to enhance irradiation and analytical techniques in Europe through IAEA projects. The support has triggered a significant increase in the number and types of cultural heritage artefacts analysed and treated, said Sunil Sabharwal, a radiation processing specialist in the IAEA. Procedures ranged from the disinfection of wooden churches and ancient books to the characterization of jewellery, woven cloth and coins. Cooperation in the characterization and preservation of artefacts through the use of nuclear science and technology is an important goal of the IAEA’s cultural heritage preservation projects, Sabharwal said.

Relics versus fungi, insects and bacteria

To preserve its historical antiquities, Romanian scientists regularly use gamma rays to treat artefacts. Stored in a six metre deep water pool at the IRASM Radiation Processing Centre in Bucharest, the source of powerful gamma rays, when activated, can kill bacteria, insects and fungi (see box). Gamma radiation works wonders to conserve artefacts by destroying the “biological aggressors,” explained Moise.

Radiation is being increasingly used for preservation. “Protecting our cultural heritage
goes back to 30 years ago when there were no large scale irradiation facilities in Romania,” said Moise. “We have through this technology been able to disinfect a number of ancient items from 500 year old religious books infested with fungi to the precious icons of the Izvoarele Orthodox Church.”

Before the artefacts are irradiated, investigations are carried out on these delicate pieces of history that determine the extent and kind of contamination, the chemical solutions used in previous restoration efforts, as well as the exact radiation dose required, Moise explained.

“One of the biggest problems we have had was to convince the art world that radiation will not destroy artefacts as the technology used is harmless. There is confusion when they hear the word radiation,” said Moise. “It doesn’t damage the precious artefacts; they don’t become radioactive, and it’s swift and effective.”

Paintings, clothes and musical instruments have also been successfully treated using gamma radiation. IRASM experts treated the entire collection of the Theodor Aman Museum in Bucharest, which had to be closed in 2004 due to damp conditions that resulted in fungi and other biological contamination of its ancient objects. Following complete refurbishment, the museum was reopened in 2013.

“Many artefacts are made from natural organic materials. They are at risk of biodegradation, becoming food for insects and microorganisms,” said Corneliu Ponta, the former Head of the IRASM Radiation Processing Centre, who played a key role in the Centre’s work in using gamma irradiation to decontaminate the artefacts of the Theodor Aman Museum.

THE SCIENCE

Gamma radiation protects cultural artefacts

Gamma radiation, also known as gamma rays, refers to electromagnetic radiation of an extremely high frequency. It is emitted as high energy photons, an elementary particle with wave-like properties.

Gamma rays are a type of ionizing radiation. At the dose levels used to protect cultural artefacts, this type of ionizing radiation inhibits reproduction of microbes at room temperature without any physical contact and thus offers a better alternative to conventional decontamination methods that are based on heat or chemical treatment. The high frequency, high energy electromagnetic waves interact with the critical components of cells. And at these dose levels, they can alter the DNA so as to inhibit the reproduction of cells.

The treatment of cultural artefacts by irradiation technology is similar to that used in the sterilization of medical devices. The cultural heritage artefacts are exposed to gamma radiation from a cobalt-60 source in the radiation facility.
Peaceful Uses Initiative (PUI) —
a glimpse into current and future projects

With more than 170 projects successfully supported, benefiting more than 130 Member States, the Peaceful Uses Initiative (PUI) has been an effective mechanism for raising additional resources to meet the needs of Member States. The IAEA hopes to carry on with this initiative to further expand the benefits of the peaceful uses of nuclear science and technology in promoting broad development goals.

Here is a glimpse into some of the major current and future PUI-supported projects that need additional financial contributions.

For more information, see: www.iaea.org/newscenter/focus/peaceful-uses-initiative

Integrated and sustainable management of water resources in the Sahel region

**Duration:** 2012 to 2016, with the possibility of extension

**Estimated budget:** €5.8 million

Freshwater resources are declining in the Sahel region, an area stretching across 13 countries, from West Africa to Central and North Africa. Effective management of the existing water resources in these countries is essential to ensuring adequate water supplies in the region.

For more information, see: www.iaea.org/technicalcooperation/Home/Highlights-Archive/Archive-2013/03222013_World_Water_Day_Sahel.html

Strengthening Africa’s regional capacity for the diagnosis of emerging or re-emerging zoonotic diseases, including Ebola virus disease

**Duration:** 2015 to 2019

**Estimated budget:** €5.8 million

In the wake of the largest and most complex outbreak of Ebola virus disease in early
2014 in West Africa, the international community recognized Africa’s need for support in developing regional capacities to manage emerging and re-emerging zoonotic diseases — diseases that can pass from animals to humans, and that, without proper management, can lead to regional and global epidemics.

This four-year project sets out to strengthen Africa’s regional capacities with mechanisms for early detection and strategies for sharing related diagnostic and epidemiological information within a regional network. The project aims to provide training, expert guidance, and infrastructure development for the implementation of a monitoring, tracing and surveillance system, including diagnostic equipment.

For more information, see: www.iaea.org/sites/default/files/pui_ebola.pdf

From the laboratories to the global community: Renovation of the Nuclear Applications Laboratories (ReNuAL)

**Duration:** 2014 to 2017  
**Estimated budget:** €31 million

For over 50 years, eight nuclear applications laboratories in Seibersdorf, Austria, have provided specialized training, support in research and development, and analytical services to assist Member States in using nuclear science and technology to address their national needs and to tackle global challenges, from animal production and health to nuclear science and analytical techniques. But without a significant upgrade since their establishment in 1962, the laboratories are no longer able to fulfil their functions in responding to the growing and evolving needs of Member States.

This project, known as ReNuAL, commenced on 1 January 2014 and consists of new building construction, the modernization of existing buildings, infrastructure upgrades and the acquisition of new laboratory equipment to replace ageing or obsolete instruments.

For more information, see: www-naweb.iaea.org/na/renual/index.html

**Strengthening nuclear power infrastructure development**

**Duration:** 2011 to 2015, with a possible follow-up project from 2016 to 2020  
**Estimated budget:** €1.5 million

Approximately 30 countries are now considering nuclear power as part of their energy mixes or have already decided to start a nuclear power programme. As countries evaluate this option or have already embarked on developing a nuclear power programme, they look to the IAEA for guidance and support.

This project sets out to further strengthen and develop guidance documents, methodologies and review services, as well as to create opportunities for sharing experiences and lessons learned. The project aims to assist and guide newcomers countries, particularly low and middle income (LMI) countries, to develop safe and sustainable nuclear power
infrastructures. This project is funded through the PUI and, in some cases, complementary activities are financed through the Technical Cooperation Fund.

For more information, see: www.iaea.org/OurWork/ST/NE/Main

**Cancer control capacity assessment and evaluation**

**Duration:** Ongoing  
**Estimated budget for 2015:** €450 000

Cancer cases are on a significant rise globally, with LMI countries often ill-equipped to effectively manage the burden of the disease and respond to the needs of patients. As countries increasingly prioritize cancer care and control, many are turning to the IAEA Programme of Action for Cancer Therapy (PACT) and the Integrated Missions of PACT (imPACT). The imPACT review missions assesses a country’s national cancer control capacities within a comprehensive approach to cancer control, and provide recommendations on how to address identified gaps and further develop their capabilities to tackle the disease.

PUI funds have supported imPACT missions to 26 Member States since 2010. The majority of these have been to LMI countries. This has helped these countries to, among others, develop national cancer control plans and programmes, and pave the way to establish national cancer care facilities equipped with diagnostic and treatment equipment as well as an adequate workforce of trained specialists. In 2015, there are plans for imPACT Review missions to six Member States.

For more information, see: www.iaea.org/technicalcooperation/PACT/index.html