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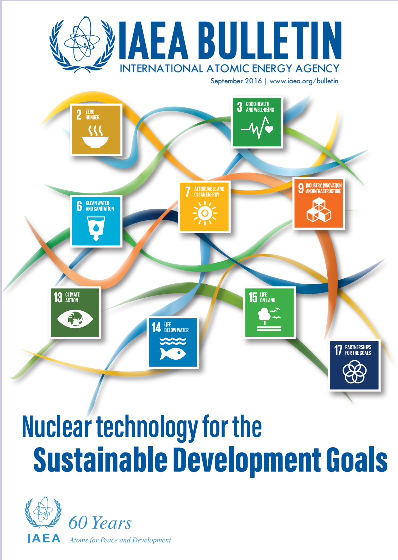
Nuclear technology for the Sustainable Development Goals

IAEA

60 Years

Atoms for Peace and Development



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IAEA

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, industry 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 and criminals, 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, including decommissioning.

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.

Building a sustainable future: atoms for peace and development

By Yukiya Amano, Director General, IAEA

Smart use of science and technology will be essential for the achievement of the 17 Sustainable Development Goals (SDGs), which were agreed by world leaders in 2015.

Nuclear technology, in particular, has many valuable applications in industry and in areas as diverse as human health, energy and environmental protection. The IAEA is uniquely equipped to help countries use nuclear science and technology to improve the health and prosperity of their people.

For 60 years, the IAEA has supported Member States in the effective use of peaceful nuclear science and technology for sustainable development. When it comes to technology transfer and capacity-building, the IAEA delivers. Its impact on the lives of millions of people around the world is remarkable and deserves to be better known.

This edition of the *IAEA Bulletin* highlights some of the ways in which the IAEA fulfils its "Atoms for Peace and Development" mandate and assists countries in achieving the SDGs. You can read about how nuclear and isotopic techniques help fight hunger (Goal 2) by improving child nutrition in Thailand (page 13) and saving the livelihoods of farmers and farm workers in South Africa (page 10).

Nuclear science also helps to increase food production by helping farmers to make better use of water, soil and crop resources (Goals 6, 14 and 15, respectively). With IAEA support, an irrigation method optimized with nuclear technology is helping women farmers save water and grow crops to feed their families and earn a living in Sudan (page 19). In Bolivia, isotopic techniques help scientists protect water resources (page 22).

Promoting good health and well-being is an important element of the SDGs (Goal 3). The IAEA assists countries such as Tanzania and Tunisia in improving access to radiation medicine (page 8) and comprehensive cancer care (page 6). Helping to reduce premature deaths from diseases such as cancer by a third by 2030 is a priority for the IAEA and for me personally.

As countries develop, demand for energy increases. Many countries believe nuclear power can contribute to achieving affordable and clean energy for all (Goal 7), while also playing a significant role in mitigating climate change (Goal 13). A number of countries are considering new nuclear power programmes. The IAEA will help them develop the necessary infrastructure and technical capacity to operate nuclear power plants safely and securely (page 26). We also support technological research and innovation (Goal 9).

We work with key partners (Goal 17) to help make nuclear science and technology widely available for sustainable development. You can read about our collaboration with governments, international organizations and leading NGOs (page 24) and how these partnerships support scientific research and policymaking (page 26).

The IAEA Scientific Forum this year showcases the contribution of nuclear science and technology to the achievement of the SDGs. Leading experts will discuss the ways in which nuclear technology can further contribute to the well-being of humanity, boost prosperity and help to protect the planet. I invite you to follow the proceedings online: www.iaea.org/scientific-forum.

"For 60 years, the IAEA has supported Member States in the effective use of peaceful nuclear science and technology for sustainable development. When it comes to technology transfer and capacity-building, the IAEA delivers."

— Yukiya Amano, Director General, IAEA

(Photos: C. Brady/IAEA)

(Photos: R. Murphy/IAEA)

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The Sustainable Development Goals and the IAEA

By Nicole Jawerth and Miklos Gaspar

The IAEA plays an active part in helping the international community with the achievement of the 17 Sustainable Development Goals (SDGs), adopted at the United Nations Sustainable Development Summit in New York in September 2015. These goals and their associated targets aim at stimulating action over the next 15 years in areas of critical importance for humanity and the planet. They balance the three dimensions of sustainable development: the economic, social and environmental.

The IAEA's support to countries in using nuclear and isotopic techniques contributes most of the SDGs. Here is a look at a selection of goals to which the IAEA contributes directly and how the IAEA achieves this.

Hunger and malnutrition are often rooted in food insecurity and agricultural challenges, which cause well-being to suffer and economies to grow strained. Through the IAEA, and its partnership with the Food and Agriculture Organization of the United Nations (FAO), several countries are improving food security and agriculture by using nuclear and isotopic techniques. They use them for a range of purposes, from conserving soil, water and crop resources, to protecting plants from insect pests and breeding new plant varieties with desirable characteristics. Others use nuclear techniques to protect the health of livestock and enhance their reproductive efficiency. As foodstuffs are prepared for consumption, nuclear techniques can be used to ensure superior quality, longer shelf life and increased safety of food.

In several Member States, nuclear tools are also used to study body composition and nutrition absorption to further research into, and improve nutrition programmes focused on, malnutrition in all forms, from undernutrition to obesity.

Achieving sustainable development is not possible if health suffers. In helping to achieve the SDG target of reducing deaths from non-communicable diseases, such as cancer, by one third, the IAEA is well-positioned to assist countries with developing comprehensive cancer control programmes and improving access to care, including establishing radiation medicine services and facilities, as well as educating and training specialized health professionals. These services rely on the IAEA's work on improving the availability and safe use of life-saving medical radioisotopes, and can be used to monitor and evaluate other health conditions, such as cardiovascular disease and tuberculosis.

When faced with diseases that can spread from animals to humans, such as the Ebola virus disease, a number of countries turn to the IAEA for support in using nuclear-derived diagnostic and monitoring tools for early disease detection to control their spread.

Water is essential to life. As populations grow and economies expand, access to clean and safe water is imperative. Isotopic techniques shed light on the age and quality of water. Some countries use this to implement integrated water resource management plans to sustainably use resources and to protect water and water-related ecosystems, while others use them to address scarcity, improve freshwater supplies and ensure their efficient use.

As society leaves its mark, water pollution is also a challenge. With IAEA support, some countries are now treating wastewater from industrial activities using radiation to reduce contaminants and improve water quality, making the water safer for reuse.

Access to clean, reliable and affordable energy is a precondition for sustainable economic growth and improved human well-being. The IAEA fosters the efficient and safe use of nuclear power by supporting existing and new nuclear programmes around the world, catalysing innovation and building capacity in energy planning and analysis as well as in nuclear information and knowledge management. Many countries also work with the IAEA to safely and securely meet growing energy demands for development, while also improving energy security, reducing environmental and health effects from energy production and mitigating climate change.

Cutting-edge industrial technologies underpin the success of strong economies, in developed and developing countries alike. Nuclear science and technology, in particular, can make a major contribution to economic growth and have an important role to play in support of sustainable development. With the IAEA's help, some countries have increased the competitiveness of their industries by using nuclear technologies to carry out safety and quality tests in industry and by applying irradiation techniques to improve product durability. Irradiation also improves industrial sustainability by helping to lower the environmental impact of industrial production.

Nuclear science, including nuclear power, can play a significant role in both climate change mitigation and adaptation. The IAEA works to increase global awareness of the role nuclear power can and does play in relation to climate change and reducing greenhouse gas emissions. Nuclear power is one of the lowest-carbon technologies available to generate electricity. The IAEA also assists countries in using nuclear techniques to adapt to and mitigate the consequences of climate change through soil, water and crop resource management. Scientific research using nuclear tools, carried out with support from the IAEA, also contributes to science-based policies and actions to address the effects of the changing climate.

Oceans contain vast ecosystems brimming with marine life. They are a vital resource for people who rely on the sea for their livelihoods, day-to-day nutrition or both. To sustainably manage and protect oceans and, in turn, support coastal communities, many countries are using nuclear and isotopic techniques, with support from the IAEA, to better understand and monitor ocean health and marine phenomena such as ocean acidification and harmful algal blooms. National, regional and international laboratory networks, established by the IAEA, also offer several countries an avenue for scientific collaboration and provide key resources for analysing and monitoring marine contaminants and pollutants.

Desertification, degrading land and eroding soils can jeopardize people's lives and livelihoods. Isotopic techniques provide accurate assessments of soil erosion and erosion hot spots. These assessments can contribute to reversing land degradation and restoring soils, which also helps to halt the loss of biodiversity.

Through IAEA support, many countries use nuclear techniques to gather key data that helps to shape agricultural practices towards more sustainable use of land, which, in turn, leads to increased incomes. Such data also supports the improvement of conservation methods to protect and restore resources and ecosystems.

Partnerships help expand access to science and technology toward achieving the SDGs. Close collaboration between the IAEA, United Nations organizations, such as the FAO and the World Health Organization, and other international as well as civil society organizations help to maximize the contribution of the IAEA's support towards the achievement of countries' development priorities. Many countries work through regional and interregional cooperation projects and agreements with the IAEA to improve their knowledge, gain access to technology and equipment, and develop best practices to promote sustainable development, research and innovation. This framework also enables specialists from different countries to connect with IAEA partners, including a global network of regional resource institutions and collaborating centres. Many of these efforts are organized through the IAEA and its technical cooperation programme, specialized laboratories and coordinated research activities.

3 GOOD HEALTH AND WELL-BEING

Cancer control in Tunisia: changing perceptions and improving access to care

By Aabha Dixit

> "Public campaign drives are regularly conducted to remove ignorance and widen awareness about the benefits and effectiveness of radiation technology for cancer treatment."
>
> *— Mohamed Faouzi Ben Slimane, Head, Biophysics and Nuclear Medicine Department, Salah Azaïz Institute–Cancer Centre, Tunis*

Cancer isn't a death sentence. If detected and treated early, it is curable. This is the message Tunisian doctors are delivering to their patients.

Increasing awareness about cancer prevention and treatment among the population at large are vital to the Tunisian Ministry of Public Health's outreach efforts. These include education about the role of radiation medicine and technology (see The Science box), and explaining to people that nuclear imaging techniques are safe, painless and cost-effective.

"There is a phobia about nuclear applications in medicine," said Mohamed Faouzi Ben Slimane, Head of the Department of Biophysics and Nuclear Medicine at the Salah Azaïz Institute in Tunis and Head of the National Radiation Protection Centre. "Public campaign drives are regularly conducted to remove ignorance and widen awareness about the benefits and effectiveness of radiation technology for cancer treatment."

A doctor uses a SPECT scan machine on a patient at the Salah Azaïz Institute–Cancer Centre of Tunis.

(Photo: Salah Azaïz Institute–Cancer Centre of Tunis)

The doctors are confident that they can overcome the psychological barrier through a well-constructed and targeted campaign that provides simple, relevant and practical information about medical imaging and radiotherapy and how it can help improve patient care. "The success is that we are demystifying the 'taboo' attached to cancer, resulting in more people coming forward for check-ups," Ben Slimane said.

About 8000 new cases of cancer were recorded in Tunisia from 2011 to 2015, according to the country's Ministry of Public Health, with lung and breast cancer being the most common. The Salah Azaïz Institute conducts over 20 000 diagnoses annually, and over 12 000 patients undergo treatment. "We have to ensure that the radiation treatment and dosages are accurate, and carefully monitored, as our priority is the care given to cancer patients," Ben Slimane added. There has been an increase in cancer cases in Tunisia over the past couple of years. The total number rose from 2553 in 1994 to 3926 cases in 2009, with an annual average increase of 3.3%. However, this average number showed a relative, but not significant decline with 3715 during the period between 2009 and 2011.

As in the majority of low and middle income countries, the growing cancer burden is putting a considerable strain on the public health system in Tunisia. With the support of the IAEA, the country's doctors are working to meet a growing demand for cancer care, which includes convincing people to undergo cancer therapy at the earliest opportunity.

Catch early, treat swiftly

Ongoing training of medical staff is essential. "Not only do these technologies help oncologists like me to view the body and select the best treatment required to deal with different types of cancer, but we also need to make sure we use the correct radiopharmaceuticals, which are vital to track the progress achieved and assess how the body is reacting and functioning," Ben Slimane explained.

This is an area in which the IAEA is playing an important role. It has assisted Tunisia with training, knowledge transfer and assistance in the proper and safe use of radioactive sources for cancer treatment. IAEA experts have conducted training for radiopharmacists and medical physicists to improve quality control and the safe use of radiation medicine and equipment.

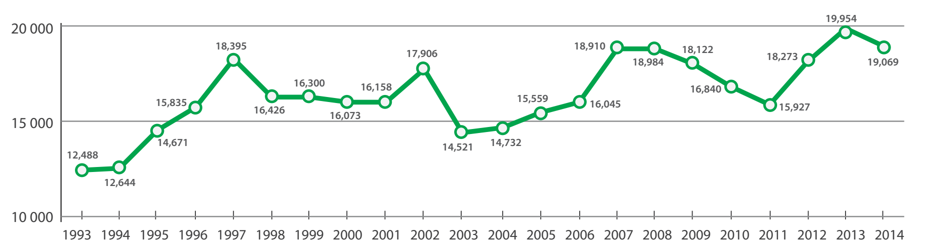
"We work hand-in-hand with medical physicists to ensure that they have the right knowledge and training to protect themselves and the patients," said Azza Hammou, a paediatric radiologist and the former Head of the National Radiation Protection Centre. "Our safety protocols are in line with IAEA safety standards." Doctors and technicians handling nuclear medical applications have to implement correct procedures while strictly following safety guidelines, she said.

Quality assurance in radiation medicine is a complex process. It covers the assessment of clinical, physical and technical aspects of diagnostic imaging and radiation treatment, as well as management controls that are essential to avoid errors, accidents and misdiagnoses. The IAEA's support includes the provision of technical guidance for implementing and reviewing quality assurance programmes for radiotherapy, nuclear medicine and diagnostic radiology at hospitals.

The IAEA has supported Tunisia in its efforts to improve cancer control for decades. The country now has 17 radiotherapy machines for its population of 10 million, placing it above most countries in Africa, said Adnan Atwa, Programme Management Officer for Tunisia at the IAEA's Department of Technical Cooperation. Since 2013, the Tunisian Government, with IAEA support, has established radiotherapy centres in Tunis, Sousse and Sfax, which are equipped with a new generation of linear accelerators (linacs). These accelerators are most commonly used to treat patients by delivering very precisely localized, high-energy X-ray irradiation to tumours. The IAEA is also assisting the country by providing specialized training, including fellowships and scientific visits, on medical physics and radiotherapy.

To assess Tunisia's cancer control capacities and provide recommendations on its comprehensive national cancer control programme, the IAEA and its partners conducted an integrated mission of the IAEA's Programme of Action for Cancer Therapy, or imPACT Review, in Tunisia in late 2013. This has helped the country identify priority actions for strengthening cancer control planning, prevention, early detection, diagnosis, treatment and palliative care capacities. It has also contributed to the enhancement of Tunisia's active cancer registry that keeps track of cancer cases.

Number of cancer tests performed at the Salah-Azaïez Cancer Institute in Tunis



Quick Facts

In 2012, 14.1 million new cases of cancer were reported worldwide, and this number is projected to reach 24.6 million by 2030.

THE SCIENCE

Radiation medicine

Nuclear and radiation techniques are commonly used in the diagnosis and treatment of a large number of health problems such as infectious and non-communicable diseases, particularly cardiovascular disorders and cancer. Nuclear medicine procedures with radiopharmaceuticals are used for the diagnosis and management of diseases. Diagnostic radiology mainly involves the use of X-rays and CT (computed tomography) in the detection of diseases. PET/CT (positron emission tomography combined with X-ray computed tomography) is a hybrid technology that allows better detection and staging of diseases by displaying both anatomical and functional abnormalities within the affected organs. Radiotherapy is used to complement surgery and sometimes chemotherapy for cancer treatment.

3D radiotherapy increases effectiveness and safety of cancer treatment in Tanzania

By Nicole Jawerth

Radiation oncologists use 3D contouring tools to examine and chart out where tumuors lie in the body in order to plan and effectively deliver radiation treatment.
(Photo: D. Calma/IAEA)

"Being as accurate as possible when irradiating a tumour is essential. We now have the skills to more fully understand the extent of a tumour and ultimately plan better and more precise treatment for our patients."

— Mark Mseti, radiation oncologist, Ocean Road Cancer Institute, Tanzania

Tanzanian doctors are now able to deliver more precise radiation treatment for cancer patients with less damage to healthy tissue. Following training and support from the IAEA in 3D radiotherapy planning, patients will have access to more effective and safer cancer care.

"Being as accurate as possible when irradiating a tumour is essential. We now have the skills to more fully understand the extent of a tumour and ultimately plan better and more precise treatment for our patients," said Mark Mseti, a radiation oncologist at the Ocean Road Cancer Institute in the capital Dar es Salaam, which receives technical support and equipment through the IAEA. He participated in a recent IAEA training on 3D planning for target volume definition and contouring for radiotherapy (see The Science box). This is part of Tanzania's shift from 2D to 3D radiotherapy planning services that will be implemented later this year after the opening of the country's first facility equipped with 3D planning tools.

"The concept of target volume definition and contouring is about making sure that the radiation we use is focusing on the disease and not on healthy tissue," explained Mseti. "If you can obtain accuracy in drawing, or contouring, the tumour, you will have a higher probability of targeting and obtaining the goals of treatment, while sparing as much of the healthy, normal tissues as you can."

Cancer is the uncontrolled division of abnormal cells in the body, and radiation can be used to stop that division. Specific doses of radiation can damage cells beyond repair, causing them to stop dividing and die. This makes radiation effective for managing and treating cancer. However, if the radiation is imprecisely or improperly targeted or delivered at the wrong dose level, the patient's healthy cells can be unnecessarily damaged, or the cancer cells may only be partially eliminated, leaving other cancer cells to continue dividing. This could put the patient at risk of health complications in the short or long term.

The IAEA supports its Member States, like Tanzania, in working to reduce the burden of non-communicable diseases like cancer. To this end, the IAEA offers training, coordinates research, provides equipment and technical expertise and hosts scientific fellows, among other services. Like Tanzania, many low and middle income countries are only beginning or planning to begin using 3D cancer treatment tools.

Expert lecturers at an IAEA training course teach radiation oncologists how to use 3D radiation therapy planning tools.
(Photo: D. Calma/IAEA)

"Radiation oncologists in low and middle income countries are sometimes limited to primarily theoretical training due to economic and resource constraints that make it difficult to access often costly hands-on courses," said Eduardo Zubizarreta, Head of the Applied Radiation Biology and Radiotherapy Section at the IAEA. "Helping doctors get the equipment they need and get expert-led, hands-on experience is essential to improve the quality of treatment."

In Tanzania, radiation oncologists have been using paper and a needle to contour in 2D, which is much less precise than the 3D method. "In my three years of training as a radiation oncologist, I had never actually contoured in 3D," Mseti said. "Everything has been theories, theories, theories. I am now ready to use these new contouring skills on patients."

The new facility, set to open later this year at the Ocean Road Cancer Institute, will be equipped, in part through IAEA support, with new 3D planning equipment, including a computed tomography (CT) machine. The Institute is expected to treat between 100 and 200 patients per day using these new tools.

Quick Facts

Investing in radiotherapy could lead to saving 26.9 million life-years for patients in developing countries and produce a net benefit for the economy of $278.1 billion in 2015–2035.

THE SCIENCE

Target volume definition and contouring for radiotherapy planning

Target volume definition and contouring are key skills used by radiation oncologists to plan how to accurately, precisely and consistently deliver radiation to treat a patient with cancerous tumours.

Using specially-designed contouring computer software, the radiation oncologist reviews 3D images based on medical scans of a patient's body to identify the location and size of cancerous tumours. These scans are taken with nuclear diagnostic imaging tools, like computed tomography (CT) and positron emission tomography (PET) machines.

Once the tumour is identified, the oncologist uses the contouring computer software to define and draw, or contour, an outline of the tumour — the target volume — and then contour the healthy organs in order to precisely and accurately plan where radiation should be delivered, how much radiation is needed based on the size and depth of the tumour and how to minimize exposure to healthy tissues and organs.

2 ZERO HUNGER

How a nuclear technique helped save the Western Cape's orange industry

By Miklos Gaspar

Citrus fruit is the second most important agricultural export commodity in South Africa, with most of the production destined for exports. The industry employs 10% of the country's agricultural labour force.
(Photo: M. Gaspar/IAEA)

> "SIT has allowed us to go green and not use chemicals against the moth anymore."
> — *Piet Smit, orange farmer, South Africa*

Every morning at 7 a.m. a small plane takes off to swoop around a fertile valley amidst the scenic mountains of the Western Cape in South Africa, offloading its cargo of 1 000 000 ready-to-mate moths. The insects have been mass-reared and sterilized using a gamma irradiator and other specialized equipment made available by the IAEA in 2007. The result: citrus orchards free of the devastation of the false codling moth in the Olifants River Valley, and an industry, once on the brink of extinction, is now thriving again.

"In just five years the infestation has gone," said Martli Slabber, who grows oranges, clementines and lemons on her 100-hectare farm. "From two infested fruits per tree every week we are down to a single one in the entire orchard per season."

The suppression of the moth has saved the livelihoods of close to 10 000 people, added grower Gerrit van der Merwe. "Without citrus, there would be no jobs here."

Slabber and van der Merwe are two of 400 citrus farmers who use the services of XSIT, a company owned by the Citrus Growers Association of South Africa, to deal with the false codling moth, which naturally resides in some parts of the country, including the Olifants River Valley. The moths' larvae feed on citrus fruits, destroying the pulp.

XSIT — named after the nuclear-based sterile insect technique (SIT) — produces and releases 40 million sterile moths every week in an area of over 15 000 hectares. Fed on an optimized diet of maize, wheat germ and milk powder, the moths are irradiated and released when they are at the height of their sexual potential. The sterile moths mate with wild insects, but this mating does not produce any offspring, diminishing the population over time (see The Science box, page 12).

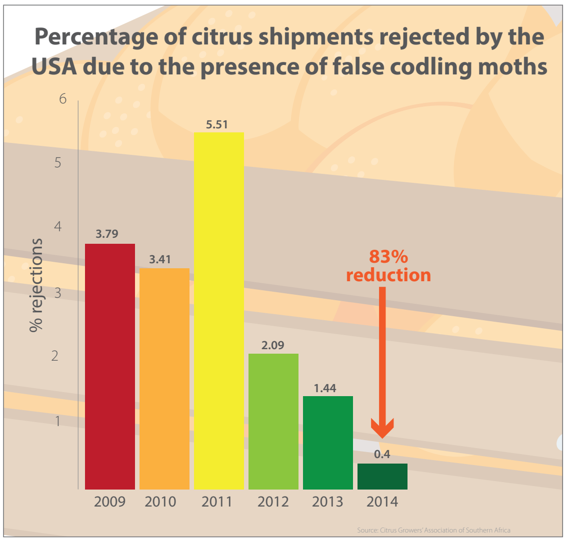
"SIT has allowed us to go green and not use chemicals against the moth anymore," said Piet Smit, who produces 11 000 tonnes of citrus a year on 250 hectares of land. "We also no longer have problems with insecticide residue levels on the fruit."

Thanks to the reduced use of chemicals, wildlife has returned to the orchard, van der Merwe added.

Citrus, the lifeblood of the region's economy

South Africa is the second largest exporter of citrus fruits in the world, with exports worth over $1.4 billion in 2014. Citrus is the country's second most important agricultural export commodity after wine. The industry employs 10% of South Africa's agricultural labour force.

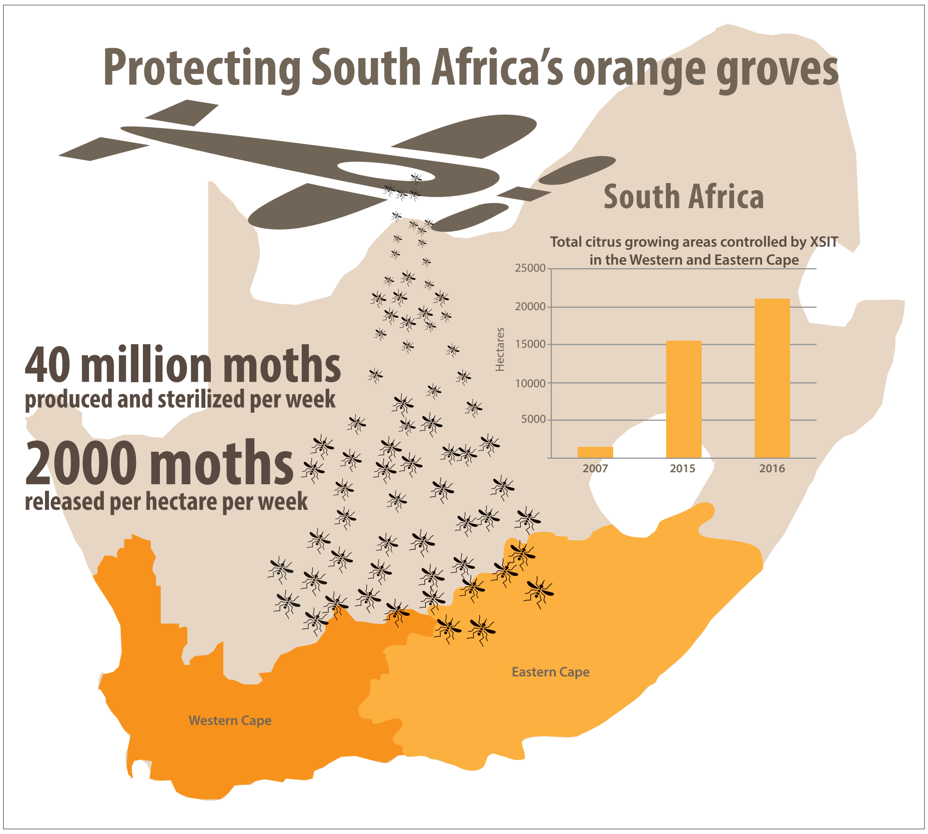
Back in 2005, the main export market for the region's citrus fruit, the United States of America, tightened import quality and infestation reduction measures, as US agricultural authorities grew concerned about the spread of the false codling moth to their country, potentially threatening their citrus and cotton industries.



Slabber, van der Merwe and other farmers in the area used to lose between 10% and 15% of their production to the pests before harvest, but the real losses came from the pest-infested fruits that made it into shipments and were returned by US inspectors. If they found just three larvae in a shipment of 160 000 oranges, they would return the entire consignment. "We were seriously considering alternative crops," Slabber recalled.

The search for a new method

It was time to find a new pest control method, explained Vaughan Hattingh, a biologist and researcher, and now Chief Executive Officer of Citrus Research International (CRI). CRI began research in radiation biology and rearing techniques to see if SIT could be adapted for the false codling moth. The IAEA, in cooperation with the Food and Agriculture Organization



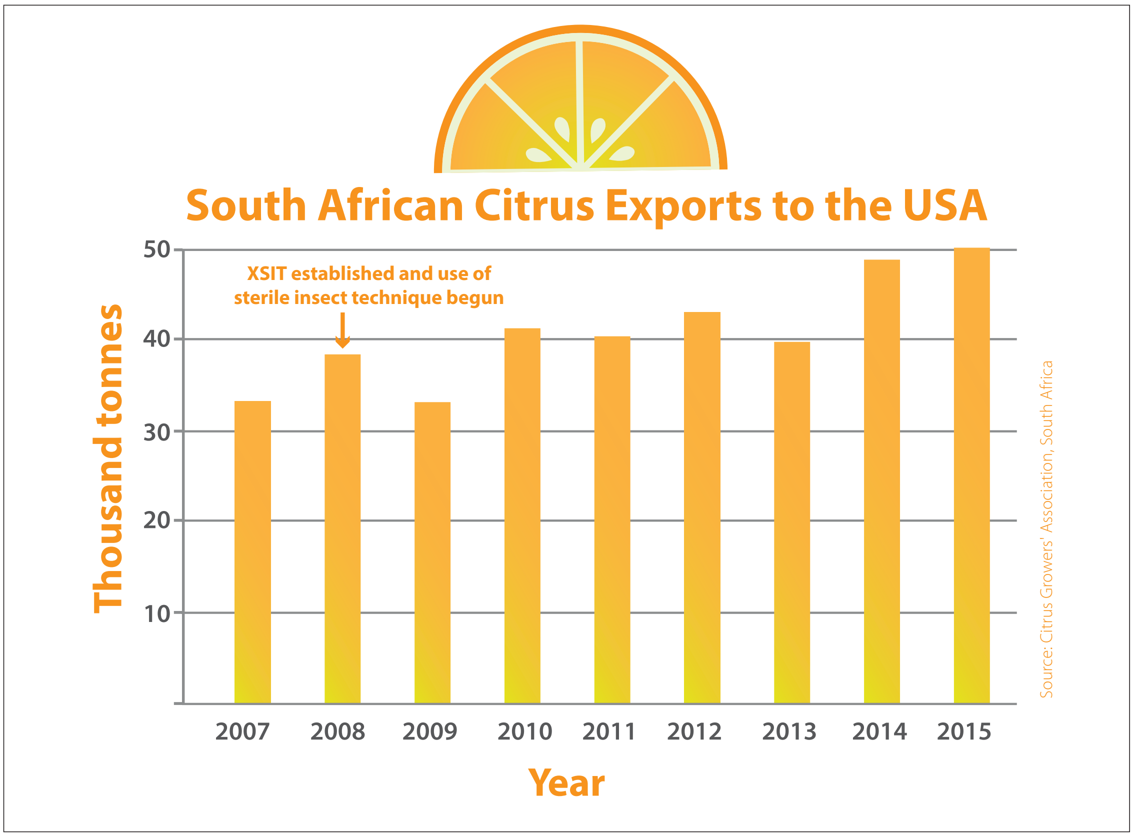
of the United Nations (FAO) and the United States Department of Agriculture, provided expertise and access to a network of specialists working on using SIT against other pests.

Thanks to funding from the IAEA's technical cooperation programme, Hattingh and his colleagues were able to get a first-hand look at a rearing facility for a related codling moth in Canada. This helped them lay the groundwork to eventually rear and sterilize enough insects to test the technique on a 35-hectare plot in an isolated and particularly infestation-prone part of Slabber's orchard.

"The results of the test surpassed our expectations," Hattingh said. "We realized that the false codling moth was a sedentary insect, so we could treat areas in isolation." It is this characteristic that makes the moth a prime candidate for SIT: controlling the insect population in a defined geographical area, even down to a single orchard, keeps the area insect-free long term because moth populations do not tend to fly far.

Public–private partnership for moth control

Following the success of the trial, the Citrus Growers Association and the South African Government co-founded XSIT in



order to develop the technique for use on an industrial scale. The area served by XSIT has increased more than tenfold since 2007, and the company has contracts in place to further expand to a total of 21 000 hectares.

Research is now ongoing not only to further perfect the technique, but also to make it available in far-flung areas of the country. The current method of producing sterile insects in Citrusdal, a town in the Western Cape, and transporting them to other areas for release works well for the neighbouring Eastern Cape, but it is not feasible for faraway places. XSIT's researchers, with support from the IAEA and the FAO, are working on a technique that involves transporting the pupae, which would then be irradiated at another location in the north-eastern part of the country.

THE SCIENCE

Birth control for insect pests

The sterile insect technique (SIT) is a form of insect pest control that uses ionizing radiation to sterilize insects that are mass-produced in special rearing facilities. These insects are released systematically over pest-infested areas, where they mate with wild populations, which subsequently do not produce offspring.

As a result, this technique can suppress and, in some cases, eventually eradicate populations of insect pests. SIT is among the most environmentally friendly control techniques available, and is usually applied as part of an integrated campaign to control insect populations.

The IAEA, in cooperation with the FAO, supports about 40 SIT field projects around the world, which are conducted within the framework of the IAEA technical cooperation programme. While most of these target pests that affect crops and livestock, research is also under way to use the technique against various species of disease-transmitting mosquitoes, including carriers of the Zika virus and malaria.

Thai scientists use nuclear technology to fight the double burden of malnutrition

By Laura Gil

Children need more micronutrients for their growth than what is provided in a typical diet. Many children in Thailand are at risk of micronutrient deficiencies.
(Photo: V. Chavasit/INMU)

Nuclear techniques contribute to Thailand's fight against malnutrition by helping scientists identify the best ways to increase nutrient levels in children. Studies carried out since 2009 with the support of the IAEA have shown that food fortified with vitamins and minerals, such as iron, zinc, vitamin A and calcium, enhance micronutrient intake and increase nutrient levels in children.

"There was a micronutrient gap in the diets of these young children, a gap that most local foods cannot meet," said Emorn Udomkesmalee, Senior Advisor and Former Director of the Institute of Nutrition, Mahidol University (INMU) near Bangkok. "By using isotopic techniques, we found a way to identify this gap and to measure how their bodies absorb and use certain micronutrients."

Children need more micronutrients for their growth than provided in a typical diet, which contains sufficient calories, but often not enough iron, zinc, vitamin A or calcium. In many developing countries, low nutrient-density food such as plants is a main part of the diet. This can result in micronutrient deficiencies — often referred to as 'hidden hunger' — that can affect hundreds of thousands of children, Udomkesmalee said. According to a 2012 survey, approximately 800 000 children under five suffered from undernutrition in Thailand, putting them at risk of micronutrient deficiencies.

"If children don't consume enough micronutrients, they do not grow properly and can become vulnerable to infectious diseases," said Christine Slater, nutrition specialist at the IAEA. Over the past two decades, Thailand has actively worked to reduce malnutrition and nutrient deficiencies through health policies and community-based nutrition programmes.

One way to prevent and control micronutrient deficiencies is to distribute food fortified with vitamins and minerals — now a common practice in Thailand. Fortified food is made by adding micronutrients to commonly consumed food, such as oil or cereals, or by biofortification, the process of growing crops with increased levels of these essential micronutrients. This fortified food is typically added as a complement to a normal diet.

Between 2009 and 2012, Thai scientists trained by the IAEA tested a food fortification

> **"There was a micronutrient gap in the diets of these young children, a gap that most local foods cannot meet. By using isotopic techniques, we found a way to identify this gap and to measure how children's bodies absorb and use certain micronutrients."**
>
> *— Emorn Udomkesmalee, Senior Advisor and Former Director, Institute of Nutrition, Mahidol University, Bangkok*

programme in children between six and 24 months old. They gave a group of children rice fortified with iron, zinc and vitamin A. After measuring their micronutrient reserves using isotopic techniques (see The Science box), they found that children who consumed the fortified rice had a significant increase in iron, zinc and vitamin A reserves, in contrast to the control group. They used a computer simulation to further confirm the suitability of the fortified rice for meeting nutrient requirements.

Before the introduction of isotopic techniques, scientists in Thailand had to rely on calculations based on select, high-nutrient food to verify whether the country's nutrition programmes were working, said Pattanee Winichagoon, Associate Professor at INMU. "Assessment was based on our knowledge and calculations and did not adequately consider elements such as the body's absorption of the micronutrients," she said.

Turning data into practice

The results of these studies are now under consideration to help further optimize nutrition intervention programmes across the country.

"We have been communicating with the Ministry of Public Health and the Paediatric Nutrition Group and already started discussions on how to make use of our analyses," Winichagoon said. If the study results are taken on board, they will lead to new pragmatic feeding guidelines on complementary foods for infants and young children, she added.

Learn today, teach tomorrow

The IAEA has been working with Thailand in the area of nutrition since 1998. The country has benefited from the IAEA's technical cooperation programme and coordinated research projects in the form of training courses, scientific visits, fellowships and equipment. Thai scientists have also been working with the IAEA to use isotopic techniques to assess exclusive breast-feeding of infants from birth to six months, and to ensure iron-fortified food is not detrimental for people with iron or other nutrient deficiencies.

Hosting courses for others to learn about isotopic techniques is a way to pay these efforts back, Winichagoon said. "It would be a shame not to share the know-how. We have so many questions, and we're not the only ones."

Nutrition is a topic of interest for Thailand and for the world, Slater said. "Improved nutrition has great consequences for society. A well-nourished child will have the adequate capacity to study when he or she grows older and will be able to earn a living as an adult. Overall, a well-nourished population helps the country develop."

Thai scientists trained by the IAEA use isotopic techniques to check how children's bodies respond to rice fortified with iron, zinc and vitamin A.

(Photo: V. Chavasit/INMU)

THE SCIENCE

Isotopic techniques and nutrition in children

Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons. Isotopic techniques track how the body takes in, uses and retains nutrients present in food that are vital to supporting healthy growth and development. Scientists use these techniques to determine bioavailability, which is the fraction of a nutrient our body absorbs and uses for growth and metabolism.

For example, to check iron or zinc absorption, patients eat test meals mixed with stable isotopes. Measurements of blood or urine samples taken later reveal how much of the isotopes have been incorporated into the body. These measurements are analysed through mass spectrometry, a method that uses a sensitive detector to selectively identify and measure various compounds.

To assess vitamin A status, patients take a dose of carbon-13 or deuterium-labelled vitamin A. Experts use a mass spectrometer to analyse blood samples taken before and after the dose of vitamin A. Based on the dilution of the precisely measured dose of isotope-labelled vitamin A, it is possible to calculate the total quantity of exchangeable vitamin A in the body.

How the IAEA assists newcomer countries in building their way to sustainable energy

By May Fawaz-Huber

As the world anticipates the climate policies that will unfold following the 2015 Paris Agreement and the adoption of the Sustainable Development Goals (SDGs), more countries are likely to include nuclear power in their national energy mixes. Newcomer States — countries introducing nuclear power for the first time — are requesting the IAEA's assistance in developing the proper infrastructure to establish safe, secure and sustainable nuclear power programmes and cope with the challenges posed by the rise in global demand for energy and the need to mitigate climate change.

"The potential role for nuclear energy has greatly increased since the historic adoption of the SDGs and the Paris Agreement," said David Shropshire, Head of the IAEA's Planning and Economic Studies Section. "The decision to use nuclear is now easier since there are only a few other large-scale, uninterrupted energy options that come with small environmental footprints."

The Paris Agreement was adopted at the Paris Climate Change Conference (COP21), at which 195 countries agreed to the first universal, legally binding agreement on climate. The Agreement confirmed the target of keeping the rise in global temperature below 2 degrees Celsius by the end of the century as compared to preindustrial times.

To address this target and the energy–climate challenge (see Box, page 16), several countries are re-evaluating their energy mixes and the potential role of nuclear energy. "Instead of being recognized as just a power source to propel economies, nuclear is now linked to climate action," Shropshire said. "Countries investing in nuclear power not only get dependable energy but also a key resource to not exceed the 2°C target."

The Polish answer

Poland, for example, plans to generate nuclear power, not only to ensure long term electricity supply and stimulate national economic growth, but also to mitigate climate change.

"Poland recognizes the importance of the Sustainable Development Goals, including the reduction of emissions of carbon dioxide and other air pollutants from the energy sector," said Józef Sobolewski, Director of the Nuclear Energy Department at Poland's Ministry of Energy. "Part of our strategy stipulates that introducing nuclear power — a zero-emission, clean and efficient energy source — is one of the means to achieve that reduction." A nuclear power programme would also be a strong stimulus for the domestic research and development sector, he added.

The IAEA is an essential resource hub for newcomer States such as Poland and other countries considering nuclear power. They can access the IAEA's energy planning tools and tap into its knowledge of nuclear power to make informed decisions about the role of this energy source in their countries.

"Once a Member State decides to use nuclear power, the IAEA can provide advice and review the development of the required infrastructure," Shropshire said.

Reaching milestones step by step

The IAEA's three-phase 'Milestones approach' facilitates the implementation

Countries like Jordan, Poland and Turkey work with the IAEA to develop sustainable nuclear power programmes.
(Photo: Jordan Atomic Energy Commission)

"Poland recognizes the importance of the Sustainable Development Goals, including the reduction of emissions of carbon dioxide and other air pollutants from the energy sector. Part of our strategy stipulates that introducing nuclear power — a zero-emission, clean and efficient energy source — is one of the means to achieve that reduction."

— Józef Sobolewski, Director, Nuclear Energy Department, Ministry of Energy, Poland

of a nuclear power programme from start to finish. This includes issues for consideration by a Member State before deciding to build a nuclear power plant (NPP), the preparations involved and the construction and commissioning of the NPP. To complement this, Member States often request an Integrated Nuclear Infrastructure Review (INIR) mission, where international experts determine whether the programme is based on an effective national policy and strategy, strong management, a proper legal framework and a skilled workforce. Drawing on this review, the IAEA develops a country-specific integrated work plan to assist newcomer States in addressing gaps in their nuclear infrastructure and conducts follow-up reviews to track their progress.

Poland reached the first milestone this year after implementing the IAEA's recommendations based on the INIR missions conducted during Phase 1 of the Milestones approach. The country aims to complete construction of the first reactor of its first NPP by 2024 and begin the construction of a second NPP by 2030. A Phase 2 INIR mission is expected to take place in 2017 to review Poland's progress with its nuclear power programme.

Toward sustainable energy in Jordan

Among other newcomer States, Jordan included nuclear power in its national strategy to mitigate carbon emissions. "Jordan's energy is almost totally dependent on imported fossil fuel, which cannot be sustainable for various reasons," said Khaled Toukan, Chairman of the Jordan Atomic Energy Commission. "The establishment of a nuclear power plant, among other alternatives, will have a significant positive impact on Jordan from the standpoints of energy cost and reliability, national income, human infrastructure and expertise building, as well as carbon emission reduction."

Upon Jordan's request, the IAEA has already conducted three INIR missions since 2009 and has provided Jordan with an action plan based on an evaluation of the country's nuclear infrastructure and the regulatory framework for nuclear and radiation safety. This year, Jordan will commission its first research and training reactor, and the IAEA will assist the country in building its capacity for future operation and effective utilization.

Nuclear power is also included in Turkey's energy strategy to mitigate climate change, according to Turkey's 'Intended Nationally Determined Contributions' report submitted under the United Nations Framework Convention on Climate Change. Through INIR missions, the IAEA has assisted Turkey in evaluating its readiness to develop a nuclear power programme. Upon Turkey's request, IAEA experts provided recommendations for a national action plan and also reviewed the country's draft nuclear energy laws. Turkey plans to build two NPPs with eight reactors to be operational by 2028 and to start building a third by 2023.

The energy–climate challenge

Without a major transformation of the global energy system, greenhouse gas (GHG) emissions would severely affect the Earth's climate. Energy-related carbon dioxide (CO_2) emissions are projected to increase from their 2013 level by about 20% by 2040. The dual 'energy–climate challenge' over the next 10 to 20 years is to substantially increase the amount of safe, reliable and affordable energy while drastically reducing GHG emissions.

Nuclear power is among the energy sources and technologies available today that could help meet the energy–climate challenge. Greenhouse gas emissions from nuclear power plants are negligible, and nuclear power, together with hydropower and wind-based electricity, is among the lowest GHG emitters when emissions over the entire life cycle are considered. It is projected that by 2050 electricity generated through nuclear power could help to eliminate about 3 gigatonnes of CO_2 emissions per year. This projection depends in part on assumptions about the relative costs and performance of low carbon technologies.

Nuclear energy for the future

By Mikhail Chudakov, Deputy Director General and Head of the Department of Nuclear Energy, IAEA

The IAEA's work relates to many of the Sustainable Development Goals (SDGs) adopted last year by the United Nations General Assembly, but three SDGs, in particular, underscore the contribution of nuclear power towards energy for the future: Goal 7 — access to affordable and clean energy — will concentrate our efforts towards realizing sustainable development as the global population grows and energy demand increases; Goal 9 — industry, innovation and infrastructure — is not possible to achieve without ample access to energy; and Goal 13 — climate action — sets out targets for clean, environmentally friendly energy.

Nuclear power produces about 11% of global electricity with 450 nuclear reactors in operation in 30 countries. Our projections show that nuclear energy will continue to play a key role in the global energy mix for decades to come. While the use of nuclear power is increasing, its share in the world's energy mix is decreasing and its economic competitiveness is being challenged. Nuclear power plants have a high upfront cost but can be competitive when one considers the cost to produce electricity over the entire lifetime of the plant. The competitiveness of any energy option is very country-specific and depends on many factors, such as available natural resources.

A growing number of IAEA Member States, several of which are concerned about climate change and about strengthening their supply of energy, are considering introducing nuclear power into their national energy mix or expanding its use (see article, page 15).

The IAEA fosters sustainable nuclear energy development by supporting existing and new nuclear programmes around the world and by providing support for new nuclear technology development. We also help Member States build local capability in energy planning and analysis as well as in nuclear information and knowledge management, while setting the foundations for nuclear safety and security.

Innovation, technological advances and new economic models can help increase nuclear power's contribution to the world energy mix and to sustainable development. New nuclear reactor designs feature enhanced safety features and can run more efficiently and produce less waste, or even consume it. Advances in the nuclear fuel cycle can further cut down on waste, making nuclear power more sustainable. Creative funding and financing arrangements between governments and the private sector contribute to technology development and help to better handle the large investment cost needed for nuclear energy infrastructure and the construction of power plants.

When considering emissions over the entire life cycle of electricity generation using different energy options, nuclear power, along with hydro and wind power, does not lead to carbon dioxide (CO_2) emissions while producing electricity and is among the lowest greenhouse gas contributors. Taking into account the whole life cycle, nuclear power among the lowest emissions comparable to those from renewable energy sources.

Renewable energy has many advantages and is clean, but one of the disadvantages is that it relies on the availability of wind or sunlight. Nuclear power is a useful complement: it can produce energy consistently and efficiently most of the year (rates exceeding 90% have been regularly achieved in several countries), day and night. Also, it can be deployed on a large scale, making it better suited to meet electricity demands of cities and industry. Looking to the future, innovative hybrid energy systems are in development to bring nuclear power together with renewables to produce electricity, or to use the heat from nuclear reactors for other applications, such as desalination of seawater.

Climate AND energy

As a low-carbon technology available today, nuclear power can help countries meet the dual energy–climate challenge, as laid out in the Paris Agreement (see Box, page 16).

The Paris Agreement, agreed under the United Nations Framework Convention on

Quick Facts

Ten new nuclear reactors were connected to the grid in 2015, the highest number since 1990.

Climate Change in 2015 by 195 countries, calls upon governments to limit the increase in the global average temperature to well below two degrees Celsius above pre-industrial levels. About a third of greenhouse gas emissions come from energy production; therefore we must decarbonize the energy sector in order to control the catastrophic effects of global warming.

The IAEA has a comprehensive set of tools to help Member States better understand and respond to the energy–climate challenge and to launch a nuclear power programme. Our efforts focus on providing a factual assessment of nuclear power. We help decision-makers consider all energy production technology options. If and when a Member State so requests, we provide assistance for the safe, secure and sustainable implementation of its nuclear power programme.

Nuclear power can continue to promote sustainable development by providing the energy needed to support a growing population and a society that continues to industrialize. It can do this while having a smaller impact on the climate and the environment when compared to most other forms of energy.

How nuclear technology helps Sudanese women make the most of their land

By Nicole Jawerth

Nuclear science helps Sudanese women turn dry lands into vegetable fields.
(Photo: N. Jawerth/IAEA)

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

"We used to have nothing. We had little food, and we had to buy it at the market. We did not even know how vegetables were grown," said Fatima Ismail, a farmer from a small village in eastern Sudan where an IAEA-supported drip irrigation project has been ongoing since 2015.

These hundreds of women have been living constrained lives with few opportunities for change. They and their families, many of whom are refugees or internally displaced, had limited food resources and relied on their husbands' meagre income. The women did not have an option to grow their own food or leave their homes to work and earn a living.

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

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

Science was the starting point of a new change for these women. Local scientists from the Agricultural Research Corporation (ARC) were trained and provided with technical support by experts from the IAEA, in partnership with the Food and Agriculture Organization of the United Nations (FAO). The scientists learned to use the soil moisture neutron probe technique to measure and determine moisture levels in their soil at Kassala Research Farm, to quantify the amount of water needed by the crops, and to optimize nitrogen fertilizer use (see The Science box). These studies then formed the basis for how much water and fertilizer to deliver through the watering system known as drip irrigation.

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

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

Scientists carry out studies on the atoms in soil, water, fertilizer and crops to determine how to best grow crops and manage soil and water resources.

(Photo: N. Jawerth/IAEA)

Quick Facts

Drip irrigation uses 60% less water than surface irrigation. It improves onion crop yields by around 8000 kg/ha. This translates to over $3700 in additional income per hectare of crops.

Every drop counts

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

“Although not a new technology in itself, it is only when set up correctly and optimized using scientific data that drip irrigation can be effective with very little water waste,” said Lee Heng, Head of the Soil and Water Management and Crop Nutrition Section of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. This fertigation method is promoted by the FAO for countries and regions where water is scarce and at a premium.

“What makes this drip irrigation system new and innovative is what has been released from ARC,” said Rashid Sir El Khatim, Coordinator from the Talawiet Organization for Development. Pilot studies were conducted in fields around Kassala State, along the border with Eritrea. The ARC provides local NGOs like Talawiet with a complete package for setting up and using drip irrigation and fertilizer, optimized through the scientific work done with IAEA support. This area is often called the ‘bread basket’ of Sudan as the soil is rich with nutrients, and when combined with adequate water, has shown to be an excellent environment for growing food. However, water supplies are increasingly running short due to rising temperatures and climate change.

“Water, soil, temperature: it’s all a complete package,” said El Saddig Suliman Mohamed, ARC’s Director General. “Without a proper irrigation system, you can’t maximize yields, but on the other hand, without using fertilizer correctly the soil can’t reach its full potential. So we have to look at the whole package.”

The success of the IAEA pilot project in reducing water use by more than 60% while increasing food yields by more than 40% drew the attention of other organizations, such as the Sudanese Red Crescent Society (SRCS) and Talawiet. They have worked closely with IAEA-trained scientists from the ARC to set up and run more than 50 small-scale farms and home gardens for over 400 women. Following the success of these projects, the ARC, Talawiet and the SRCS are now working with their partners to establish more than 40 new drip irrigation systems for over a thousand women.

Women’s empowerment for sustainable change

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

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

As the project continues, the women are eager to continue building on their success.

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

Small-scale farms and home gardens equipped with drip irrigation systems are helping to empower women in Sudan.
(Photo: N. Jawerth/IAEA)

THE SCIENCE

Soil moisture neutron probe and nitrogen tracking

Scientists use a neutron probe to monitor moisture levels in soil at a research farm. The probe emits neutrons that collide with the hydrogen atoms of water in the soil. This slows down the neutrons. The change in neutron speed is detected by the probe and provides a reading that corresponds to the moisture level in the soil. The higher the number of hydrogen atoms, the more neutrons are slowed down, and the number of slow neutrons, which can be measured, serves as an indication of the level of moisture.

Nitrogen is a key component of soil and fertilizers. As nitrogen atoms interact with the atoms in soil, fertilizer and water, they change into forms taken up by plants, released in the air or absorbed further into the ground. Using fertilizers labelled with nitrogen-15 (15N) stable isotopes — atoms with extra or missing neutrons — scientists can track the isotopes to determine how effectively the crops are responding to and taking up the fertilizer. This can help increase crop yield and optimize fertilizer use.

Managing water resources: Bolivia uncovers aquifer's secrets with nuclear technology

By Laura Gil

In certain regions of Bolivia, people depend on water from aquifers for many uses.
(Photo: L. Potterton/IAEA)

More than 2000 years old: that is one of the secrets stored in the atoms of water that flow in the Purapurani aquifer hidden underground in Bolivia. Despite centuries of supplying water to the cities of El Alto and Viacha near the capital of La Paz, little was known about Purapurani. But with the help of nuclear technology, scientists are gathering key details about the age, quality and source of water in the aquifer. This information is helping them find ways to protect and sustainably use this valuable resource.

"Thanks to isotopes, we are unveiling our aquifer's secrets," said Paola Mancilla Ortuño, hydrologist at the Ministry of Environment and Water. "Now we know that in the northern area of the aquifer, water at shallow levels is sadly contaminated. We also know that part of the water in the eastern area is possibly over 2000 years old. And we also know that groundwater in another part of the aquifer comes from rainwater in the Andes Mountain Range."

Purapurani is a key resource for development in the area, where more than a million people depend on this 300 km² aquifer. "The two cities have developed economically thanks to Purapurani," Mancilla Ortuño said. A growing population relies on it for everyday use, companies draw heavily from it to keep up with urban expansion, and farmers need it to sustain their crops and livestock.

The IAEA has helped Bolivia establish its first isotope hydrology laboratory, and since 2012, IAEA experts have been training a group of Bolivian scientists on the use of isotopic techniques to assess water resources and determine their origin, age, vulnerability to pollution, movement and interactions, both above and below ground (see The Science box, page 23). "Isotopic techniques give us useful information that we could not get from other methods. This gives us a wider vision," Mancilla Ortuño said.

"Isotopic techniques give us useful information that we could not get from other methods. This gives us a wider vision."

— Paola Mancilla Ortuño, hydrologist, Ministry of Environment and Water, Bolivia

The improved capacities allow scientists to answer questions they could not properly address before: How old is the water and where does it come from? Is it still of good quality? How much of it is left? The answers to these questions help advance scientific research on Purapurani and shape water protection and management policies to reflect the aquifer's potential and limits.

What they studied and found

Bolivian scientists study the water's age because it indicates roughly how long it takes the aquifer's resources to replenish — in this case, thousands of years — and helps to estimate the aquifer's supply limits. Similarly, they check for contaminants to determine threats to the aquifer that could jeopardize its future use. At Purapurani, contamination has only been identified in a limited area of the aquifer and is likely related to river water mixing with aquifer water.

"Now that we know where the water comes from, we have to protect the aquifer's sources to ensure its sustainability and quality," said Rafael Cortéz, Consultant for the Ministry of Environment and Water and lecturer at San Andrés University. As the next step, he and his team of scientists plan to build artificial water recharge schemes to guarantee a stable supply of rainwater.

The Purapurani aquifer

While Bolivia's humid lower lands (jungle) host major groundwater basins, populated cities like La Paz, El Alto and Viacha are located on the highlands, where water is scarce. The three cities depend on the water from the 300 km^2 Purapurani aquifer.

Two worlds

Working with the IAEA has yielded another benefit to Bolivia: a multidisciplinary team of chemists and hydrologists.

"With these projects we are bringing together experts from different disciplines, hydrologists and chemists," said Luis Araguás Araguás, isotope hydrologist in the IAEA's Division of Physical and Chemical Sciences. "A hydrologist doesn't usually study isotopes, and a chemist doesn't usually study water resources. Thanks to our projects, they meet and exchange their expertise."

The team is now working to apply isotopic techniques to the aquifers of the city of Oruro and to replicate the same studies in other cities of Bolivia. Bolivia has five main large urban aquifers, but only three have been studied so far. The recent hydrological studies supported by the IAEA are gaining attention in conferences at the national level, and universities have now introduced the concept of isotope hydrology in their curricula.

"We've grown with each project," Cortéz said. "We have crawled, stood up, learned to walk, and are now starting to jog."

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. 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, which is known as the 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 water that contains 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 water 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.

17 PARTNERSHIPS FOR THE GOALS

Partnerships and atoms for peace and development

By Nicole Jawerth

(Photo: N. Jawerth/IAEA)

Achieving the Sustainable Development Goals (SDGs) is not a task carried out in isolation: the 17 goals and their targets are a comprehensive approach to global development that relies on strong coordination. This is reflected in Goal 17 on partnerships. The IAEA and its partners form important strands of this global agenda by helping countries use nuclear science to meet their development targets and achieve a lasting impact.

"The SDGs are a major undertaking that no country, organization or person can reach alone; partnerships are vital to their success," said Emma Webb, Head of the IAEA's Strategy and Partnership Section. "The IAEA plays an active role in building and cultivating cooperation worldwide toward achieving these goals."

As countries implement their national development strategies and plans, many turn to the IAEA and its partners to help them use nuclear science and technology to meet their objectives. Longstanding IAEA partnerships, such as the one with the Food and Agriculture Organization of the United Nations (FAO) and cooperation with the World Health Organization (WHO), allow international organizations to contribute their skills and resources in their respective areas of expertise to support development worldwide. Over 90 countries already have country programme frameworks in place that identify areas of cooperation with the IAEA in support of national development priorities.

The IAEA, in cooperation with its partners, supports countries in building their capacities, expanding their networks and sharing knowledge through technical cooperation projects and coordinated research activities. This takes the form of training, fellowships, the provision of equipment and expert guidance, among others. Through this, professionals strengthen their knowledge, sharpen their skills and get the tools they need to achieve sustainable results such as improving health through radiation medicine (see page 6) and ensuring energy for the future by safely and securely adding nuclear power to a national energy mix (see page 15).

Science, technology and innovation are key dimensions of sustainable progress. Cooperation enhances knowledge sharing, technology transfer and evidence-based decision-making.

In line with the targets of Goal 17, international and regional IAEA projects provide a platform for developing and developed countries to join efforts and expand their knowledge of and access to scientific expertise as well as further technological innovation for development. They also enable specialists to work collaboratively to examine and tackle issues, such as how to mitigate the climate change effects of greenhouse gas emissions from agricultural production (see page 26), and improve or learn new skills, such as 3D radiation therapy planning for cancer care (see page 8).

Through this scientific work, scientists can collect the data decision makers need for evidence-based policies and programmes (see Box). The strong emphasis on data and monitoring under Goal 17 provides further space for the IAEA and its partners to support results-oriented development planning and programming.

"The peaceful uses of nuclear science and technology have a unique role to play in responding to countries' national priorities and in supporting sustainable development," said Webb. "It is in part through these partnerships between the IAEA, governments and other entities, that science and technology can help support communities and can help deliver on the ambitious global commitment of the SDGs and advance the five 'Ps' outlined in the Agenda 2030 preamble: people, planet, prosperity, partnerships and peace."


(Photo: B. Benzinger/IAEA)

(Photo: S.Loof/IAEA)

(Photo: D. Calma/IAEA)

Precise progress

At each step of the way towards achieving the SDGs, scientists and officials need ways to track and understand their progress to refine and strengthen their efforts. In many cases, nuclear science and technology offer precise and effective ways to measure that progress and collect data to help shape policies. Some countries, like Thailand (see page 13), use nuclear techniques to study the effectiveness of nutrition programmes to improve health, while others, such as Bolivia (see page 22), use these tools to evaluate water resources to ensure clean and sustainable water supplies for the future. With such data, policy makers can take informed decisions, which can then be translated into national policies and programmes to help them achieve their national plans, goals and targets.

Combining precise scientific data and partnerships helps drive the development and reach of environmentally sound technologies. In some countries, like Sudan (see page 19), local organizations have teamed up with IAEA-supported scientists to scale up the use of irrigation systems optimized with nuclear data to conserve resources while ensuring good crop husbandry. Similarly, public–private partnerships in countries such as South Africa (see page 10) help to expand the use of a nuclear-based insect pest birth control method to stave off damaging insects. This helps save crops, improve livelihoods and protect and increase exports.

Such links between public, private and civil society organizations are an important dimension to how the IAEA cultivates cooperation in multiple directions and expands the practical application of nuclear science and technology.

Scientists join forces to study soil to find ways to reduce greenhouse gas emissions

By Nicole Jawerth

> "We can expand our knowledge and develop a good network by interacting with scientists at different stages of research. With so many different experiences, it helps all of us to speed up this research process that can otherwise take years."
>
> *— María Adriana Nario Mouat, researcher, Nuclear Energy Commission, Chile*

Balancing the use of fertilizer, water and soil in agriculture has proven useful for reducing greenhouse gas (GHG) emissions, which drive climate change and global warming. But striking an optimal balance requires an understanding of how these factors are influenced by different soil and environmental conditions as well as farm management practices. To help chart out ways to do that, scientists are increasingly using isotopic techniques to develop scientifically based guidance that helps reduce and mitigate GHG emissions.

"In Brazil, we are already producing crops and meat using processes that help mitigate GHG emissions while having a minimal environmental impact, but we need to better understand the impact of these processes on agriculture and emission reduction," said Segundo Urquiaga, a researcher from the Brazilian Agricultural Research Corporation who has participated in an ongoing project on mitigating GHG emissions supported by the IAEA, in partnership with the Food and Agriculture Organization of the United Nations (FAO). "That's how working with the IAEA is helping us."

Brazil has been working with the IAEA for over 30 years to study the environmental impact of agriculture, which has generally accounted for over 35% of its GHG emissions. The country has successfully reduced GHG emissions by around 20%.

Participants at the free air carbon dioxide enrichment experiment site at the Justus Liebig University Giessen, Germany.
(Photo: M. Zaman/IAEA)

The IAEA and the FAO provide a platform for scientists from around the globe to work together in the use of isotopic and related techniques to study the natural processes occurring in soil, plants and fertilizer under different climate conditions and to optimize agricultural practices to protect resources while reducing GHG emissions.

Agriculture contributes over a fifth of the global release of GHGs caused by human activity, according to the Intergovernmental Panel on Climate Change. Greenhouse gases, such as carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), trap heat in the Earth's atmosphere by absorbing thermal radiation from the Earth, which in turn increases the Earth's temperature. While the greenhouse effect is a natural process through which the Earth regulates its temperature and supports life, the excessive amount of GHG emissions have led to global warming.

The international community is working through agreements such as the United Nations Framework Convention on Climate Change to minimize the release of GHGs and mitigate their impact.

Learning from each other

Through these global studies, scientists expect to refine how they approach mitigation and get a better idea of how these processes work. Some countries, like Brazil, are more advanced in their research, and their experience is an important resource for those just starting out. But as each country faces unique environmental conditions and experiences, even more advanced countries can learn in the process.

"We can expand our knowledge and develop a good network by interacting with scientists at different stages of research. With so many different experiences, it helps all of us to speed up this research process that can otherwise take years," said María Adriana Nario Mouat, a researcher from the Chilean Nuclear Energy Commission.

Reducing GHG emissions (see The Science box) related to agriculture is one central aspect of combating climate change, but it has to be done in a balanced manner, so that farmers can still produce enough food and earn a living, said Christopher Müller, a soil and plant expert from Justus Liebig University Giessen in Germany. "There are so many factors that can influence how these natural processes work from one ecosystem to the next. If we can better understand how these factors work, we could help shape agricultural practices that improve our global situation while protecting soil resources."

As the scientific data is gathered, it can be incorporated into national approaches to GHG mitigation, said Nario Mouat. "Policymakers need this information so they can make decisions on how they can mitigate these gases in a country, and also how to incentivize farmers to adopt these methods. What we are doing now is part of that process," she said.

Digging into the details

Isotopic techniques are helping scientists uncover the details of the natural processes involving soil, plants and fertilizer. These techniques involve isotopes, which are atoms of the same element that have the same number of protons, but different numbers of neutrons. Nitrogen-15 is a stable isotope of nitrogen, while carbon-13 is an isotope of carbon. Both occur naturally in soil, fertilizers, water and plants. It is possible to use these isotopes to measure and track how and when gases such as CO_2 and N_2O are formed, released and absorbed.

"Isotopic techniques are extremely precise and allow scientists to better understand what's happening at each step of the process, something that conventional techniques cannot offer," said Mohammad Zaman, a soil scientist at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. "This also helps in identifying how farmers can sustainably grow crops, save water and reduce the use of expensive fertilizers, all while protecting the Earth's precious resources."

Free air carbon dioxide enrichment study on permanent grassland at the Justus Liebig University Giessen, Germany.

(Photo: M. Zaman/IAEA)

Quick Facts

The estimated economic losses due to nitrous oxide released from chemical fertilizer amounts to around $469 million per year.

THE SCIENCE

Managing greenhouse gas emissions

Soil is a mixture of minerals, organic matter, gases and water. Carbon is a key ingredient of soil structure and health, but, in gaseous form, it is a significant part of GHG emissions. Plants capture carbon in the form of CO_2 from the air, transforming it into organic matter and thereby transferring it into the soil, which boosts soil productivity and resilience to harsh climate conditions. Creating conditions with plants, soil and fertilizer to encourage this process is a method for mitigating GHG concentration in the atmosphere, which is known as carbon sequestration.

Nitrogen is a ubiquitous element present in soil, as well as in gaseous form as N_2O in the atmosphere. N_2O has a global warming potential almost 300 times that of CO_2. It has many sources, but in soil it is naturally produced when microorganisms and bacteria transform nitrogen from ammonium — a component of fertilizers and manure — into nitrates, which are more easily taken up by plants. The processes of transforming ammonium and nitrate are called nitrification and denitrification. By carefully optimizing the use of certain fertilizers and manure in agriculture, N_2O releases can be minimized while still allowing plants to thrive.

New IAEA handbook helps doctors deal with social aspects of nuclear or radiological accidents


(Photo: D. Calma/IAEA)

"Historically, the main concern of medical professionals was the symptom. The patient was a carrier of symptoms to which observation, medical reasoning, and techniques were applied. Therefore, the medical concern did not extend much farther than the biological body. Even when operating in a public health capacity, it was not seen as the responsibility of medical professionals to understand socio-cultural factors, even when they had an obvious influence on outcomes.

The Fukushima nuclear power plant accident of March 11, 2011 has challenged these assumptions."

So starts the preface of a new handbook for health professionals compiled following the Fukushima Daiichi accident under the coordination of the IAEA and introduced at a conference for medical professionals in Singapore in June 2016. The goal: to better prepare medical staff for the unexpected, including dealing with the psychological effects of disasters.

"If we can assist medical personnel in communicating effectively with the affected population, the health outcomes will improve as well," said May Abdel-Wahab, Director of the Division of Human Health at the IAEA. "A tool like this handbook gives medical staff information to help people have better control over their lives and make appropriately informed decisions."

Over 100 medical professionals from nine countries participated at the Third Technical Meeting on Science, Technology, and Society (STS) Perspectives on Nuclear Science, Radiation, and Human Health: The View from Asia, organized jointly by the IAEA and the National University of Singapore.

A series of IAEA projects to help build the capacity of medical professionals, physicists and other specialists in Asia and elsewhere to communicate about radiation-related health risks in a nuclear or radiological emergency also concluded with the organization of this meeting. The initiative focused on the need for clear and science-based communication about possible health effects of radiation during and after any such emergency.

Medical and social

Understanding the social dimensions of disasters is key to finding solutions, said Koichi Tanigawa, Vice President of Fukushima Medical University, who was involved in the preparation of the handbook. "The Fukushima accident taught us that what is required in medical response to a nuclear accident extends beyond ordinary medical expertise."

Anxieties regarding radiation can be exacerbated by lack of scientific understanding, which the medical community needs to be able to deal with. "Radiation specialists thought they would be able to persuade people" about the level and risk of radiation following the Fukushima Daiichi accident, said Atsushi Kumagai, Associate Professor at the Education Centre for Disaster Medicine at Fukushima Medical University. "Instead, people just followed their own hunch."

There is a need for medical professionals to acquire a broader understanding of the relationship between patients and society. This is particularly relevant to disaster situations, as knowledge of the social aspects becomes increasingly important in establishing and maintaining a relationship between professionals and citizens, according to the handbook.

"Back in 2011, the biggest challenges were scarcity of information on radiation among the public, and lack of coordination among responding organizations," said Tanigawa, who led a radiation emergency medical team dispatched to Fukushima following the disaster. "A science–technology–society project may address the roles of individuals responding to these difficult situations."

Communicating about risks is a challenge for doctors and health managers, he explained. "Health care professionals need to learn how to communicate with residents who have different perceptions about radiation, provide scientific information to the public as risk communicators, and facilitate their understanding of health risks, so that the residents can adapt their lives accordingly."

The handbook provides an overview of general radiation history and the circumstances of release of radiological material in Japan.

It addresses risk perception and advises on how best to deal with psychosomatic symptoms. Topics related to preparing for and coping with disasters and risk communication are also covered, along with legal and ethical considerations.

Although the context of the handbook is Japan following the Fukushima Daiichi accident, medical professionals throughout the world may find it useful, Tanigawa said. “These outputs should be included in the core curricula of medical education not only in Japan, but also in other countries in order to better prepare for unexpected events such as a major nuclear or chemical accident or an outbreak of infectious diseases.”

The handbook can also be useful to a wider audience such as journalists and the general public, Abdel-Wahab said. “The ability to help the affected population cope with disasters is not restricted to doctors alone.”

— By Miklos Gaspar

Seventeen ways to change the world: IAEA promotes the role of nuclear technologies in sustainable development at European Development Days

The IAEA hosted an exhibition on nuclear sciences and applications for sustainable development at the 2016 European Development Days in Brussels, Belgium. The exhibition featured panels explaining how nuclear techniques can help countries tackle global challenges.

(Photo: B. Benzinger/IAEA)

What do food and water insecurity, limited access to health care, climate change and land degradation have in common? Nuclear techniques can help address all these priority areas for international action under the 2030 Agenda for Sustainable Development. The connection between global challenges, sustainable development and nuclear technologies was the focus of an IAEA panel discussion at the 2016 European Development Days (EDD), marking the first time the IAEA held an event at this forum.

The IAEA’s participation at the tenth EDD, one of the first major conferences to address the implementation of Agenda 2030, also included an exhibition explaining the use of nuclear techniques in food and agriculture and their development impact (See Box, page 30).

Making informed decisions

“If we are to preserve global biodiversity and halt further losses we need to understand the dynamics — down to the level of the atom — of environmental systems and the interplay between them,” said Martin Nesirky, Director of the United Nations Information Service in Vienna and the moderator of the ‘Interactive Lab Debate’.

Mohammed Yassin, Head of the Forestry Research Centre of Morocco’s High Commission for Water, Forestry and Desertification Control, spoke of the role of isotopic techniques in tackling the effects of climate change, particularly drought leading to a reduction of up to 75% in grain yields. “Using isotopic techniques, we were able to accurately assess soil erosion and the effectiveness of soil conservation practices and make concrete recommendations to policymakers,” he said. “These all delivered real change for people who rely on the land for their livelihoods.”

The scientific community has an important role to play in supporting the 17 Sustainable Development Goals (SDGs), particularly with regard to strengthening the role of data to improve understanding of climate change and supporting effective policy responses, said Andreas Richter, Director of the Austrian Polar Research Institute at the University of Vienna. “One of the main tasks of the scientific community is to provide independent, evidence-based data to allow politicians and societies at large to make informed decisions to reach their development goals.”

Showcasing success

In addition to the Interactive Lab Debate, the IAEA also participated in the EDD Global Village, showcasing three projects conducted through the IAEA's technical cooperation programme and the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture. These projects relate to tackling soil erosion in Viet Nam, supporting food safety controls in Chile, and fighting the Zika outbreak in countries from Latin America and the Caribbean with the help of the sterile insect technique.

At the IAEA's stand, visitors were able to examine pupae, larvae and adults of various types of insect pests that can be suppressed using the sterile insect technique. Visitors also had the opportunity to learn about soil sampling and, using a handheld molecular sensor, were shown how to analyse the protein and fat content of various products.

David Osborn, Director of the IAEA Environment Laboratories, spoke of the role of isotopic techniques in understanding and sustainably managing environmental systems. "If we are to have confidence that our use of natural resources, such as soil, food and water, is truly sustainable, we must pursue a better understanding of how the natural environment works and how we are impacting it," Osborn said. "Nuclear science equals precision science which equals better environmental management." He also highlighted how the IAEA uses nuclear and isotopic tools to prevent, adapt to, and better understand the potentially wide-ranging consequences of small changes in our environment.

The IAEA is offering support to Member States in using nuclear techniques to help them achieve the SDGs or to track their progress towards the achievement of the targets, said Ana Raffo-Caiado, Director of the Division of Programme Support and Coordination at the IAEA's Department of Technical Cooperation. "Member States have called on the United Nations and the international community to support the production of statistics and data to strengthen monitoring and measuring of results," she said. "Nuclear techniques allow rapid, accurate data gathering, which can be used to support policymakers and quickly deliver change to people on the ground. But it is clear that we cannot do this alone. We must work in partnership with others to deliver sustainable development solutions that respond to Member States' needs.

— By Omar Yusuf

The IAEA team at the 2016 European Development Days, Brussels, Belgium, 15–16 June 2016. (Photo: B. Benzinger/IAEA)

Gearing up for uranium mining: Botswana establishes environmental radioactivity monitoring

A gamma spectrometer donated by the IAEA is used to measure naturally occurring radiation in Botswana.
(Photo: M. Gaspar/IAEA)

What do elephant dung and gold mine tailings have in common? Both provide excellent samples to establish the level of naturally occurring radioactivity in Botswana's efforts to define baseline levels for background radiation as the country gets ready to license its first ever uranium mine.

"We need to be able to monitor any possible radiation release to the environment as a result of uranium mining — but to be able to do that we first need to establish how much naturally occurring radiation there is," said Richard Shamukuni, Chief Radiation Protection Officer at the country's Radiation Protection Inspectorate.

People are exposed to natural radiation from the sun, cosmic rays and also naturally occurring radioactive materials found in the earth. It is important to regulate industries that work with materials that emit naturally occurring radiation in order to protect the public against its effects, Shamukuni said.

That's where elephant dung comes in. Elephants devour hundreds of different plant species, and naturally occurring radiation present in these plants will appear in the manure. "Using the dung sample saves us from having to analyse the various plant species one by one," he explained. Gold mine tailings are also analysed because small quantities of uranium are often naturally present in gold ore.

IAEA assistance

Until 2014, Botswana did not have the equipment or know-how to carry out environmental radioactivity measurements. With the help of the IAEA, the Radiation Protection Inspectorate has since set up an environmental monitoring laboratory fitted with gamma and alpha spectrometry systems as well as other equipment and materials required for radioactivity monitoring. Most radioactive sources produce gamma rays and alpha particles, which have various energy levels and intensities. The respective spectrometry systems can be used to detect and measure these types of radiation.

The IAEA, through its technical cooperation programme, recently funded fellowships for a nuclear chemist and a radioecologist from Botswana. They learned how to operate the equipment and manage the experiments for environmental radioactivity monitoring by working alongside experienced scientists in Portugal and South Africa.

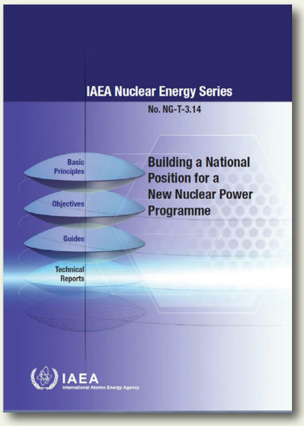
Botswana's new environmental monitoring laboratory currently analyses around five samples per week. Most of these have shown radioactivity levels that were in line with normal background levels. A few samples from the country's Central District, near where uranium mining is planned, have shown slightly higher background levels. "More studies are needed before uranium mining can start," Shamukuni said.

The government has recently approved the environmental impact assessment of the uranium mine planned near Serule village, some 350 km north of the capital Gaborone. Putting in place regular monitoring of soil, groundwater and air samples is part of the plan.

"Botswana is building a centre of excellence in the region for the measurement of environmental radioactivity," said Martina Rozmaric, a radiochemist at the IAEA involved with the Botswana project. "This is extremely important for a country that plans to start uranium mining in a couple of years."

— By Miklos Gaspar

Publications Alert



Building a National Position for a New Nuclear Power Programme

provides guidance to countries seeking to establish a national position on the introduction or re-establishment of a nuclear power programme. It provides direction to political decision makers, energy experts and other stakeholders about the process for establishing a national position as countries prepare national nuclear energy policies. It also helps countries build a consistent and durable national position for nuclear power on the basis of sound energy planning and greater public involvement in order to maintain the country's long term commitment, indifferent to possible political changes in a country.

IAEA Nuclear Energy Series No. NG-T-3.14; ISBN: 92-0-102216-5; 20.00 euro; 2016
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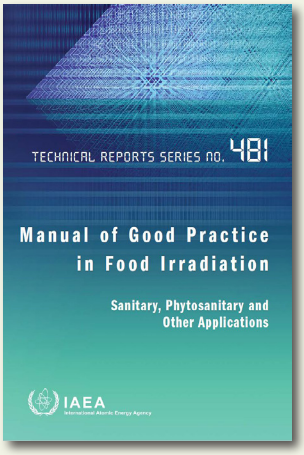

Manual of Good Practice in Food Irradiation

aims to help operators of irradiation facilities to appreciate and improve their practices and also to provide detailed, yet straightforward, technical information for food regulators, manufacturers and traders, among others, who also need to understand 'good practice' related to food irradiation. Ensuring that the process of irradiating food consistently delivers the desired results is essential for the correct use of the technology and will help to inspire consumer confidence in irradiated food.

Technical Reports Series No. 481; ISBN: 978-92-0-105215-5; 48.00 euro; 2015
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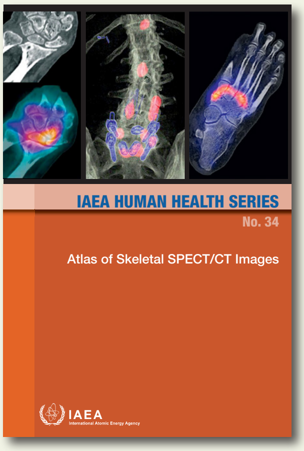

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IAEA Human Health Series No. 34; ISBN: 978-92-0-103416-8; 75.00 euro; 2016
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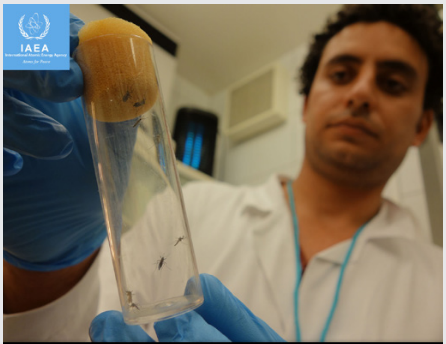

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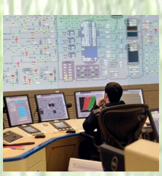

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