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COLLABORATING FOR OUR CLIMATE

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IAEA

The International Atomic Energy Agency's mission is to help 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, as well as for protective actions to reduce existing radiation risks.

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

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

The IAEA is headquartered at the Vienna International Centre. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.

IAEA collaborating against climate change

By Rafael Mariano Grossi, Director General, IAEA

The scale of climate change driven disasters is growing. This year, over a third of Pakistan was submerged in flooding from rainfall and glacier melt, displacing and impacting the lives of hundreds of millions of people.

Wildfires burn forests in Europe, droughts destroy crops in southern Africa and storms batter the Caribbean. Climate change affect us all, but the most vulnerable communities are shouldering the heaviest burden.

While the global situation looks grim, hope lies in the ingenuity of human solutions to address a human-caused problem. Our climate crisis is driven by the burning of fossil fuels, releasing greenhouse gases into our atmosphere. While coal, oil and natural gas have been critical to societal and technological development over the past 200 years, the heat-trapping properties of their emissions are warming our planet and affecting our weather systems, our ocean and the health of our planet.

Cutting our emissions and adapting to the increasingly challenging future conditions of our planet is now a priority for every country and region in the world. To this end, the IAEA has an important role to play.

In this edition of the IAEA Bulletin, we delve into how nuclear science and technologies can help address climate change and meet our Member States' priorities. We show how the IAEA collaborates with governments and researchers around the world to bring climate solutions to fruition and bolster the capacity of communities to tackle the challenges they face.

Good data is the basis of sound decisions. Scientists and decision makers rely on IAEA isotopic data to measure climate change. Our reference materials for greenhouse gases are the global standard and are used to quantify, trace and identify emission sources. Together with the World Meteorological Organization we are working to expand the use of isotope measurements for greenhouse gases across Africa, Asia and the Pacific, Europe, and Latin America and the Caribbean.

In mitigation, nuclear energy has played a central role. Over the past five decades it has avoided the release of more than 70 gigatons of carbon dioxide. Globally, more than 400 reactors still supply the world with about a quarter of its low-carbon energy and today around 30 countries are considering or embarking on new nuclear power programmes. This Bulletin looks at one of those programmes and describes how its lessons are being shared with other countries. Nuclear energy already plays a crucial role in mitigating climate change and providing energy security. In these pages the International Energy Agency's executive secretary elaborates this point.

While mitigation is fundamental to climate action, it is evident we also need to adapt to the current impacts of climate change. Nuclear science offers us a suite of climate adaption tools and solutions and we share examples from Africa, Asia and Latin America.

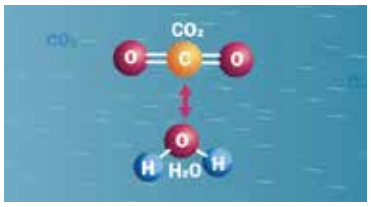
Nuclear science and technology have for decades been crucial parts of the climate change solution, both in mitigation and adaptation. It is clear the world needs more low-carbon energy and more opportunities to adapt. That means the world needs more nuclear.

"Cutting our emissions and adapting to the increasingly challenging future conditions of our planet is now a priority for every country and region in the world. To this end, the IAEA has an important role to play."

— Rafael Mariano Grossi, Director General, IAEA

(Photo: ENEC)

(Photos: IAEA)



Q&A

IAEA UPDATES

What is climate change, and how does nuclear help measure and monitor it?

By Joanne Liou

From melting glaciers and shrinking lakes to destroyed harvests and increased health risks, the impacts of climate change are visible and tangible. A particular location's climate can be described as its average weather conditions over a significant period of time, and climate change refers to shifts in those weather patterns. Warmer temperatures are changing weather patterns and disrupting nature's equilibrium and our daily lives.

Globally, temperatures have increased to about 1.1 degrees Celsius above pre-industrial levels, and the past seven years have been the warmest on record, according to the World Meteorological Organization (WMO). However, warmer temperatures are just the beginning of the story.

"Climate change is changing the face of our world," said Oksana Tarasova, Senior Scientific Officer at the WMO. "Through increasing temperatures, sea level rise, increasing intensity of extreme events, climate change impacts our life and property."

While natural factors, such as volcanic eruptions and plant decomposition, influence the climate, scientists agree that human activity is the main driver of climate change. Burning fossil fuels — namely coal, oil and gas — and clearing land and forests generate emissions of greenhouse gases (GHGs), such as carbon dioxide (CO_2) and methane, that trap heat and lead to higher temperatures.

The latest WMO report confirmed that greenhouse gas concentrations reached a record high in 2021. The concentration of carbon dioxide measured 415.7 parts per million (ppm) globally, or about 50 per cent above pre-industrial levels.

"Reducing human impact on climate would mean addressing greenhouse gases emissions," Tarasova said. "The question is: how can we do it in the most efficient way?"

The answer is in the air, and it is revealed by stable isotopes.

Stable isotopes

Stable isotopes are non-radioactive forms of atoms. Nuclear techniques are used to measure the amount and proportion of isotopes in matter, and this information — the isotopic signature — can be used to determine their source.

In order to address climate change, scientists are studying air samples and using nuclear techniques to determine the source of the problem. "We need to understand the sources,

Climate change has led to more extreme weather events — from more intense hurricanes and torrential floods to record-breaking temperatures and persisting droughts. (Photo: Unsplash)

the sinks (which is anything that absorbs more carbon from the atmosphere than it releases) and the isotopic composition, or isotopic signature, of carbon dioxide," said Manfred Gröning, Head of the IAEA Terrestrial Environmental Radiochemistry Laboratory. "The isotopic composition of carbon dioxide in a sample of air is like an identity card that reveals if it came from a natural or industrial process."

By identifying the source of emissions, more effective and efficient efforts can be implemented to target the polluters and to reduce GHGs in the atmosphere. "There may be a wildfire in one area, agricultural activities and the deterioration of plants in another area, and then the burning of fossil fuels. All that plays into the complexity of climate change," Gröning said. "We want to scientifically identify those sources of emissions."

Reference materials

Climate change has no borders and affects all parts of the planet. A unified approach for global monitoring depends on standardizing isotopic measurements, and this is where the IAEA plays a major role.

"The IAEA has experts not only in isotopic analysis but also in developing reference materials," said Federica Camin, an IAEA Reference Materials Specialist. Reference materials are physical standards that are used to calibrate laboratory equipment. Since the 1960s, the IAEA has developed and distributed reference materials for laboratories to assist in quality assurance of results using nuclear analytical techniques.

"When measuring mass, the kilogram is the standard of measurement. When measuring GHGs, reference materials provide that standard so that laboratories are aligned on the same measurement scale, independent of location. That's what you need for a global monitoring system," Camin said. The IAEA has developed a carbonate standard in the form of a white powder housed in a small vial. "From this powdered solid carbonate, laboratories can produce carbon dioxide gas to calibrate their analytical instruments," she said.

To improve users' access to CO_2 reference materials, the IAEA is in the process of producing gaseous reference materials that will be easier for laboratories to utilize. "About 40 laboratories in the world are spearheading the measurement of stable isotopes in greenhouse gases in the atmosphere. These labs require standards," Camin said. "We are developing three new CO_2 gas reference materials so that more laboratories can use them, and thus contribute to a high quality dataset of greenhouse gases in the world." The new reference materials are expected to be distributed in 2024.

Reference materials are physical standards that are used to calibrate laboratory equipment. (Photo: IAEA)

Lab support

The accurate measurement of atmospheric GHG concentrations and of their isotope ratios is extremely complicated, Gröning said. These measurements require sufficient laboratory equipment, protocols and human resources to ensure comparable data. Only a few institutions are qualified to measure isotopes for tracking and tracing GHG emissions to their exact source. In 2021, to help close gaps in global measurements, the IAEA and WMO launched their first joint technical cooperation project to help establish capacity for isotope measurements, particularly of methane emissions, across Africa, Asia and the Pacific, Europe, and Latin America and the Caribbean.

"In the next decades, more methane will be released into the atmosphere from the melting permafrost," Gröning warns. Globally, understanding how the release of methane could develop and how methane is transferred, decayed, or destroyed will help to inform scientists of the processes and measures needed to mitigate climate change. The IAEA is in the process of developing methane gas reference materials.

By developing capacities for using isotopic techniques to monitor measurements, more data can be collected and added to the WMO's Global Atmospheric Watch. The programme is used to monitor GHG trends in the Earth's atmosphere. "We need more measurements and higher quality data to understand our outlook in the years and decades to come," Gröning added. "It will take time, but there is a lot of potential for results," he said.

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— Manfred Gröning, Head of the IAEA Terrestrial Environmental Radiochemistry Laboratory

South–South and triangular cooperation

By Artem Vlasov

Global partnerships are essential for combating climate change, with some of the most impactful delivered through South–South and triangular cooperation.

South–South cooperation is the mutual exchange of knowledge and resources between countries in the Global South, including Latin America and the Caribbean, Asia and the Pacific, and Africa. As countries improve their expertise and infrastructure regarding nuclear science and technology, their experience and skills become a valuable source of knowledge for others attempting to follow a similar path.

Triangular cooperation involves the participation of third parties, such as donor countries or international organizations, in South–South initiatives in order to accelerate progress.

The IAEA seeks to promote partnerships with and between countries in the Global South. Through South–South cooperation, the IAEA's technical cooperation programme helps them to apply nuclear and related techniques to address development challenges, including those related to climate change.

The IAEA brings countries together to find solutions collectively through a range of regional and interregional projects, designated Collaborating Centres and regional training centres, as well as the four regional cooperative agreements:

ARCAL
Regional Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean

ARASIA
Co-operative Agreement for Arab States in Asia for Research, Development and Training related to Nuclear Science and Technology

AFRA
African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology

RCA
Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific

Plant mutation breeding in Asia and the Pacific

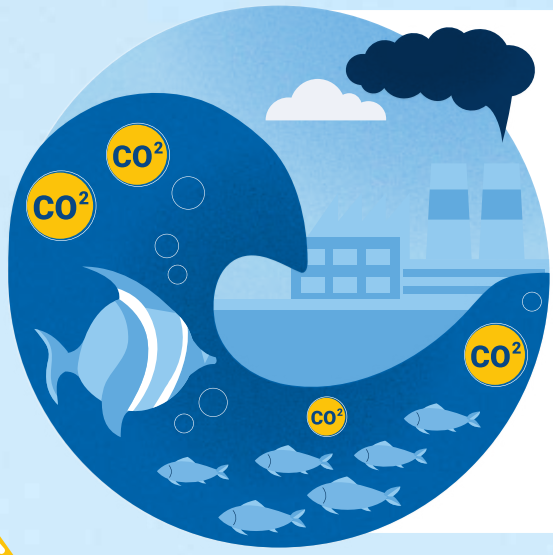
Plant mutation breeding makes a valuable contribution to the adaptation of agriculture to climate change by developing improved crop varieties with higher yields or increased resistance to drought.

With IAEA support, Indonesia's National Research and Innovation Agency (BRIN) has developed new varieties of rice, soybeans and other crops. BRIN now shares knowledge with other countries in Asia and the Pacific and beyond by providing training and hosting scientific visits and fellowships for plant breeding professionals.

Water management in Africa

As clean, fresh water becomes increasingly scarce, water management has become key to achieving a sustainable future.

With IAEA assistance, between 2012 and 2017, scientists from 13 countries in northern Africa's Sahel region teamed up to conduct the first-ever region-wide assessment of groundwater using isotopic techniques. The project took place in an area spanning five million square kilometres and found significant reserves of good-quality water.



Ocean acidification in Latin America and the Caribbean

Acidification poses a serious threat to the world's oceans. In the Latin America and Caribbean region, 18 countries are working together to collect data through nuclear and isotopic techniques in order to monitor the impacts of acidification and other stressors on vulnerable ocean ecosystems.

The Research Network of Marine-Coastal Stressors in Latin America and the Caribbean (REMARCO) was set up in 2018 under the auspices of the IAEA. The data gathered by REMARCO scientists can help policymakers to make evidence-based decisions that will protect marine life and the people who depend upon it.

Climate-smart nuclear solutions for drought-struck Angolan cattle

By Zhu Liu

During southern Angola's long dry season, water becomes scarce. The smallholders that make up 80 per cent of the region's cattle owners are forced to frequently move their herds great distances to find available pastures. They maintain an extensive livestock rearing and production system that relies heavily on grazing on natural pastures — pastures at risk from weather variations and climate change.

This year, the country's southern provinces are experiencing a fifth consecutive year of drought, killing livestock, decimating crops and affecting some 1.6 million people. The drought and worsening climate conditions, described by the International Federation of Red Cross and Red Crescent Societies as the most damaging in 40 years, are catastrophic for pastures and the smallholders' cattle production, impacting farmer's livelihoods and the country's food security.

"To help Angola and smallholders adapt to all these weather and climatic variations and changes, we need smarter solutions," said Joaquim Ipanga Nganza from Angola's Veterinary Research Institute. Nganza is working with the IAEA and Food and Agriculture Organization of the United Nations (FAO) on a two-year IAEA technical cooperation project to develop a climate-smart pasture management system using nuclear and related technologies.

"Improving our knowledge on the nutritive value of pastures and the nutritional status of cattle can help. In the process, we can help mitigate the effects of climatic variations and climate change and reduce the impact on the environment caused by overgrazing and degradation," Nganza said.

With FAO–IAEA assistance, Angola is establishing an animal nutrition laboratory and is evaluating the diet of cattle and the nutritive value of available pastures. The study will help identify a selection of nutritious grasses for multiplication and dissemination, as well as for livestock feed supplementation and ration formulation.

Smallholders' cattle production in Angola is directly affected by weather variations and climate change, as cattle graze mainly on natural pastures.
(Photo: Adobe Stock)

"Nuclear and related techniques offer substantial advantages over conventional techniques, and could help us to design a balanced diet for cattle with a mix of natural pastures and feed supplements. This can enhance cattle productivity and set a foundation for climate-smart agriculture in Angola," said Victor Tsuma, the project leader and a livestock reproductionist from the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. He explained how the project will use stable carbon isotopic techniques and near infrared reflectance spectroscopy (NIRS) to identify the nutritive value of local pastures consumed by cattle.

Tracing stable isotopes to save pastures

Stable isotopes are non-radioactive forms of atoms, which can be used in a broad variety of applications and assessments. Under grazing conditions, scientists can measure stable isotope concentrations in plants eaten by animals and compare them to what is found in faecal samples to determine which types of pastures are eaten by the cattle.

Using this stable carbon isotope tracer technique, NIRS can predict cattle's dry matter intake and develop a plant profile of that intake. NIRS is a rapid and non-destructive technique widely used in agriculture and can help Angolan scientists analyse the nutrient content of the pastures.

"Data from infrared reflectance spectroscopy can help in recommending a set of supplements, such as minerals and vitamins, to incorporate into the cattle's diet to cover the nutritional needs," said Tsuma, explaining that the farmers could partially or completely replace conventional animal feeds with more innovative practices using local resources, directly impacting productivity while protecting the environment and conserving natural resources.

Integrated, holistic and community-based approaches have been found to support a sustainable increase in animal production. Mixed crop-livestock systems produce about half of the world's food. In such systems, the output of one process becomes the input of another, and there is minimum nutrient leakage to the environment, for example, in the form of greenhouse gas emissions.

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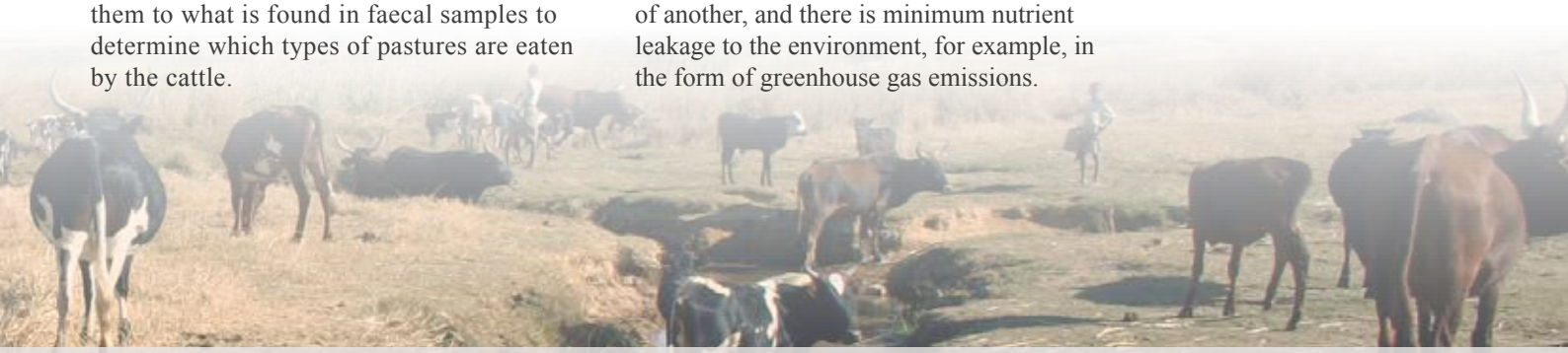

Nuclear Saves supports climate solutions

In June 2021, the 'Nuclear Saves' partnerships initiative was launched to provide an opportunity for companies and organizations to support the IAEA in transferring nuclear science and technology to developing countries, with a view to improving the health and prosperity of millions of people around the world. Through the partnerships, the IAEA is uniting the best of global science, technology and human ingenuity to help countries address some of the world's most pressing challenges. Funds from the partnerships enable the IAEA to accelerate the peaceful uses of nuclear energy for cancer diagnosis and treatment; the prevention and control of zoonotic diseases; and climate change adaptation and mitigation, as well as the transition to clean energy.

The IAEA is looking for more partners to join the initiative. To join and for more information, contact partnerships@iaea.org.

Sustainably tapping into North Africa's groundwater resources with isotope hydrology

By Joanne Liou

There is more to freshwater resources than meets the eye. While fresh water is visible in the form of rivers, lakes and glaciers, fresh groundwater resources — hidden beneath the Earth — often go unseen.

Groundwater is found in spaces within soil, sand and rock, and is stored in, and moves slowly through, aquifers. It accounts for 99 per cent of Earth's fresh water, and, according to the United Nations Educational, Scientific and Cultural Organization (UNESCO), nearly half of the world's urban population depends on it. This dependency on groundwater is expected to grow in light of the effects of climate change.

The volatility of rainfall patterns and the frequency of extreme weather events, as well as the challenges posed by pollution and intensive agriculture, affect the distribution and availability of water resources, explained Yuliya Vystavna, an isotope hydrologist at the IAEA. This is particularly relevant in arid and semi-arid regions of Africa, which experience high rates of evaporation, little rainfall and are largely dependent on groundwater resources. "In order to cope with these challenges and the scarcity of water, we need to have an understanding of water resources and manage them in a sustainable way," she added.

Uncovering groundwater characteristics

North Africa, home to the Sahara Desert, is one of the driest regions on the planet. Tunisia, located in the northernmost part of the African continent, suffers from variability in rainfall and ranks among those countries with the least water resources in the Mediterranean, said Rim Trabelsi, Director of the Department of Geological Engineering and member of Tunisia's Laboratory of Radioanalysis and Environment (LARAE) of the National Engineering School of Sfax (ENIS). "That's why groundwater is really the most reliable resource for the sustainable development of Tunisia, and the population is depending more and more on groundwater supplies."

Morocco's National Centre for Nuclear Energy, Sciences and Technology (CNESTEN) plays a leading role in the application of isotope techniques across Africa and the Middle East.
(Photo: CNESTEN)

The increased use of groundwater has highlighted the need to better understand the links between groundwater recharge and discharge — the movement of water from surface water to groundwater and vice versa. "Groundwater management is increasingly important because of climate variability causing groundwater levels to decline throughout the year, and because of the quality risks posed by nitrate pollution, or salinization by seawater intrusion," Trabelsi said.

By studying isotopes of water, scientists can provide guidance on how to protect and manage this resource. The amount of naturally occurring stable isotopes of water, and of other substances, is used to reveal the water's origin, movement, quality and age, as well as to identify sources of contamination. Water age, measured by the concentration of specific isotopes, for example, can range from months to millions of years. The age of groundwater is key to predicting the presence of contaminants, and to understanding how quickly aquifers are replenished.

'Young' groundwater can be replenished by surface water from precipitation but can also be affected by pollution and changing climatic conditions, Trabelsi explained, while 'old' groundwater, which takes much longer to replenish, is less likely to be contaminated or affected by changes in climate.

Growing analytical capacity

As in many scientific fields, the application of isotope hydrology tools and analysis requires building capacity.

When Hamid Marah first began working in the field of water resource management in Morocco in the 1990s, water samples had to be sent to countries outside of Africa for analysis. There were no laboratories in Africa that had the capability to analyse stable isotope compositions, said Marah, Scientific Director at Morocco's National Centre for Nuclear Energy, Sciences and Technology (CNESTEN). "Thanks to IAEA support, over the years the capabilities of the continent have been enhanced, and we now have several laboratories in Africa that can analyse isotopes reliably."

Through the IAEA's technical cooperation programme and coordinated research projects, isotope hydrology tools are spreading across Africa, enabling scientists to sustainably tap into groundwater resources. Over the past ten years, almost half of the IAEA's climate change adaptation projects, including water resource management projects, have taken place in Africa. Countries such as Morocco and Tunisia are playing a leading role in the application of isotope techniques across the continent and the Middle East.

Since 2009, LARAE and CNESTEN have been AFRA regional designated centres, and in 2015 CNESTEN became an IAEA Collaborating Centre focusing on water resources assessment and management. AFRA, which stands for the African Regional Co-operative Agreement for Research, Development and Training related to Nuclear Science and Technology, is an intergovernmental agreement established by African countries to strengthen and enlarge the contribution of nuclear science and technology to socio-economic development on the African continent. LARAE and CNESTEN regularly train scientists from across Africa and the Middle East and have carried out thousands of isotope analyses for national hydrological studies and IAEA-supported projects, which aim to address water availability and quality issues related to aquifers and basins.

In a 2020 study, for example, groundwater samples from an aquifer in central-west Tunisia were analysed by LARAE for chemical and isotopic measurements. In recent decades, the expansion and development of irrigated agriculture has depleted surface water resources. The study helped to determine the groundwater's suitability for drinking and irrigation, and identified sources of salinity variation. The study, which was supported by the IAEA through a coordinated research project, was published in the journal Agriculture, Ecosystems & Environment in June 2021.

There will be an opportunity to learn more about groundwater resources and their role in climate change adaptation and mitigation at the IAEA's International Symposium on Isotope Hydrology, to be held from 3 to 7 July 2023 in Vienna, Austria.

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— Rim Trabelsi, Director at Tunisia's Laboratory of Radioanalysis and Environment

Nuclear science helps Bangladeshi farmers resist climate change

By Artem Vlasov

Over the past two decades, Bangladesh, with its low-lying river delta and lengthy coastline, has been listed among the top ten countries most affected by climate change, according to the Global Climate Risk Index. Two-thirds of the country lies below sea level and is highly prone to ever-intensifying floods, cyclones, storms, droughts and landslides. As the effects of global warming become more pronounced, they expose crops' vulnerability to extreme weather and pose a growing threat to the food and nutrition security of Bangladeshis, almost 40 per cent of whom work in agriculture, according to the International Labour Organization.

Nuclear science and technology offer the means to improve the productivity of agriculture while also increasing its resilience to climate change. Through a nuclear technique known as plant mutation breeding, Bangladeshi specialists have developed improved varieties of crops, including rice, chickpea, mung bean, lentil and soybean.

"Natural hazards that come from the increased rainfall, rising sea levels and tropical cyclones are expected to increase as the climate changes, seriously affecting agriculture, water and food security," said Mohammad Abul Kalam Azad from the Bangladesh Institute of Nuclear Agriculture (BINA). "Using plant mutation breeding, we can produce crop varieties that are more resistant to drought, salinity, high and low temperatures, plant diseases and pests, and offer higher yields with shorter growing times."

BINA has successfully produced a total of 85 types of different crops, including an improved variety of rice called Binadhan-14, developed in record time. While it typically takes 8 to 12 years to produce a new variety, the Bangladeshi experts completed the task within just 4 years. Binadhan-14 was developed through an innovative technique in which experts used an ion beam rather than gamma rays or X-rays, as is usually the case.

Thanks to the new variety, Bangladeshi farmers now harvest almost seven tonnes of rice per hectare — 75 per cent more than the world's average yield per hectare.
(Photo: N. Jawerth/IAEA)

Thanks to the new variety, farmers now harvest almost seven tonnes of rice per hectare — 75 per cent more than the world's average yield per hectare. While rice normally takes between 100 and 160 days to grow, depending on the variety, Binadhan-14 is at the lower end of this spectrum; it is harvested just within 105 to 115 days after sowing. While the optimum temperature for rice cultivation is between 25 and 35 degrees Celsius, Binadhan-14 is tolerant to temperatures as high as 38 degrees, Azad explained.

Bangladesh is the world's fourth largest producer and consumer of rice, and the new varieties adapted to the changing climate are set to help feed the country's 165 million people, almost a third of whom are moderately or severely food insecure, according to a 2022 report by the Food and Agriculture Organization of the United Nations (FAO). Thanks to plant mutation breeding, rice production in Bangladesh has tripled in recent years.

Enhancing agriculture in Asia

Nuclear-based techniques offer a fast, efficient, environmentally friendly and cost-effective solution for expanding genetic diversity in crops, said Totti Tjiptosumirat, Head of the Center for Isotopes and Radiation Application at Indonesia's National Research and Innovation Agency (BRIN) — a designated IAEA Collaborating Centre in Jakarta.

By exposing seeds or other plant propagules — such as buds, suckers or spores — to radiation, scientists generate spontaneous novel and random genetic variations that can result in a wide range of new plant varieties with new traits. These new variants can be selected for desirable characteristics. The application of nuclear techniques helps speed up natural breeding processes significantly and is considered safe.

"Induced genetic variation is what distinguishes mutation breeding from other modes of plant breeding," said Shoba Sivasankar, Head of the Plant Breeding and Genetics Section at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. She explained that several advanced biotechnologies are utilized in the mutation breeding pipeline to improve the precision of selecting target traits and to speed up the process of crop variety development.

"The exchange of knowledge encourages researchers and breeders to develop new varieties," Tjiptosumirat said, adding that the designation of BRIN as an IAEA Collaborating Centre has helped host extensive training programmes for nearly 20 countries from across Asia.

Yields from rain-fed agriculture are projected to fall by 10 to 50 per cent in the Asia region by 2030 as a result of climate change, according to various estimates. As an IAEA Collaborating Centre for plant mutation breeding, BRIN assists its neighbour countries in improving the quantity and quality of agricultural produce in the face of rising global temperatures by providing irradiation services and by hosting training courses and fellowships.

This comprehensive partnership connects BRIN with research institutes, government agencies, agricultural companies, farmers and other stakeholders in the region, to strengthen food and nutrition security, increase farmers' incomes, promote sustainable farming practices and preserve natural resources.

Using plant mutation breeding, we can produce crop varieties that are more resistant to drought, salinity, high and low temperatures, plant diseases and pests, and offer higher yields with shorter growing times.

— Mohammad Abul Kalam Azad, Bangladesh Institute of Nuclear Agriculture

UAE combats climate change with nuclear power and shares its experience

By Michael Amdi Madsen

By anyone's standards, the United Arab Emirates (UAE) is a hot place to be in the summer. Temperatures during that season are regularly in the 40-degree Celsius range and, on occasion, exceed the 50-degree mark. Climate change is exacerbating the situation. The country of almost 10 million people, is categorized among those with the highest rate of vulnerability to climate change impacts, with warmer weather, less rain, droughts, higher sea levels and more storms expected. Keeping the country habitable in the long term means addressing climate change.

"As the global climate crisis worsens, the need for new nuclear power is growing. The world can learn from the lessons of the UAE and ensure a decarbonized future."

— Liliya Dulinets, Head of the IAEA's Nuclear Infrastructure Development Section

One way the UAE is addressing climate change is by reducing the carbon footprint of its energy system with nuclear power — a strategy that, through cooperation with the IAEA, it is helping to replicate in other countries.

In 2007, after careful consideration, the UAE decided to develop a civilian nuclear energy programme. Just eight years after construction began in 2012, a nuclear power reactor of South Korean design, the first in a series of four, was connected to the UAE grid. The new nuclear power plant situated in Barakah, almost 300 kilometres west of the country's capital, Abu Dhabi, is the first in the Arab world.

"Many countries are pursuing new nuclear power programmes, but the UAE is special in successfully kick-starting a programme and realizing commercial nuclear energy in such a short time, with all of the safety standards and regulations we expect today," said Francois Foulon, Professor, Chair of Nuclear Engineering and Director of the Emirates Nuclear Technology Center at Khalifa University.

Foulon works closely with the IAEA in coordinating activities where experts from other countries can visit and learn from the UAE's experience. In this capacity, Khalifa University has been designated an IAEA Collaborating Centre for nuclear energy infrastructure and human resources since 2017.

"When the UAE embarked on its nuclear programme, it started with limited infrastructure and capabilities: very few nuclear engineers, no nuclear experience, nuclear legislation nor comparable role models for such a large project," Foulon explained. "The country has had to build almost all of this from scratch. The IAEA helped along the journey, so now the country is giving back and sharing its experiences to help others realize their nuclear power ambitions."

Decarbonizing energy in the UAE and beyond

Major drivers for the UAE to pursue nuclear power have been its reliability, 24-hour availability, and baseload low carbon power, Foulon said. Low carbon nuclear power is critical for the country as it pursues a 2050

'net zero' strategy that aims for 14 gigawatts of clean energy capacity by 2030.

Barakah is contributing to this with two units currently in commercial operation, the third one in the process of starting up and the fourth in the final steps of commissioning. Once its four reactor units are complete, they could deliver up to a quarter of the UAE's electricity. The Emirates Nuclear Energy Corporation (ENEC) expects the plant to produce up to 5600 megawatts of electricity — enough to power 574 000 households in the country for a whole year. They say this will prevent the release of 22.4 million tonnes of carbon emissions annually, the same amount of carbon 350 million trees would absorb over 10 years. This is also equivalent to a quarter of the UAE's emissions reduction pledge submitted to the United Nations climate conference, COP26, in 2021.

Other countries are also interested in harnessing nuclear power for its climate change mitigating power, and today around 30 countries are considering embarking on nuclear power. With the support of the IAEA, the Khalifa University Collaborating Centre is sharing its know-how with some of those countries.

"The UAE's nuclear power plant development experiences have become a shining light on the hill for all newcomer nations; the lessons are clear and amazing," said Kufre Friday Akpan, Principal Scientific Officer at the Nigeria Atomic Energy Commission. In 2019, he took part in the IAEA's Nuclear Power Infrastructure Development School on implementing national requirements for nuclear programmes, hosted in the UAE. The experience gave him the opportunity to visit the UAE and meet and learn directly from experts from the UAE's Federal Authority for Nuclear Regulation (FANR) and ENEC.

"The Khalifa University Collaborating Centre gives experts from the around the world the opportunity to learn from the UAE's experiences and its pathway towards nuclear power," said Liliya Dulinets, Head of the IAEA's Nuclear Infrastructure Development Section. She works closely with the Centre to organize training events in the country and maximize the lessons others can learn. Over the years, the Collaborating Centre has organized numerous training events, including a course on nuclear education and human resource development for nuclear embarking countries such as Malaysia, Saudi Arabia and Viet Nam.

Dulinets said the UAE's hosting of the International Ministerial Conference on Nuclear Power in the 21st Century in 2017 was a springboard for greater visibility of the country's nuclear success. In 2023, the country will be in the global spotlight as it hosts COP28 in Dubai. Dulinets is now coordinating with the Collaborating Centre to further enhance cooperation and implement specific training courses for newcomer needs. "As the global climate crisis worsens, the need for new nuclear power is growing. The world can learn from the lessons of the UAE and ensure a decarbonized future."

Once Barakah's four reactor units are complete, they could deliver up to a quarter of the UAE's electricity.
(Photo: ENEC)

Mass melt

A new nuclear application to predict the future of glaciers

By Joanne Burge

Globally, glaciers have been losing mass since the 1970s. The ratio of fresh snowfall to ice melt has been tipped off balance by global warming. These great ice structures are melting, weakening, collapsing and disappearing without precedent around the world. The result is flooding, droughts, threatened water supplies and weakened economies, all contributing to the catastrophic impacts of climate change. With so many lives dependent on glaciers for drinking water, agriculture, hydropower and tourism, accurately predicting and planning for what will happen to them next is critical.

Switzerland relies on its glaciers, but they too are melting fast. According to the Swiss Academy of Sciences, glaciers in the country lost more than six per cent of their volume in 2022, the worst year on record. Researchers say that the Aletsch glacier, the largest in Switzerland, could lose half its ice volume by the end of the century.

Glaciologists traditionally track glacier movement using markers, such as rods, photographs and historical paintings, to compare ice changes over time. Incidental markers, such as crashed aeroplanes, can also signal glacier movement. Now there is another, more precise method, which can help glaciologists more accurately model glaciers' behaviour and, in turn, predict their future. This can support decision makers in planning for the glaciers' retreat or total disappearance.

Around 40 kilometres south of the country's capital, Bern, Spiez Laboratory has developed a nuclear technique based on the signature recorded in ice during the nuclear weapons tests (NWTs) of the 1950s and 1960s. These NWTs generated and released into the atmosphere artificial radionuclides that settled in the surface layers of glaciers around the world. As the dates of these NWTs are known, identifying peak concentrations of these radionuclides, as well as radionuclide dispersion patterns owing to ice flow, can define the ice layers' chronology.

"We used an existing technique of measuring radionuclides in soils and other solid material and, for this first time, applied this to water, ice and snow," said Stefan Röllin, a researcher from the Nuclear Chemistry Division at Spiez Laboratory.

Radionuclide detection in ice

In 2019 and 2020, Spiez Laboratory experts and members of the Swiss Armed Forces scaled the Aletsch and Gauli glaciers in

Glaciers in Switzerland lost more than six per cent of their volume in 2022, the worst year on record. (Photo: Spiez Laboratory)

the rugged terrain of the Bernese Alps to collect invaluable isotopic data on their ice flows. They extracted around 200 surface ice samples from each glacier, each sample weighing up to 1 kilogram — a large enough quantity to detect the low levels of radionuclides. They then melted the samples and applied radiochemical methods to extract and purify uranium and plutonium isotopes, which they analysed using a highly sensitive instrument called a multi-collector inductively coupled plasma mass spectrometer, or MC-ICP-MS.

The researchers also applied other nuclear techniques that can detect the presence of NWT radionuclides in environmental samples, including high resolution gamma ray spectrometry, which detected the presence of caesium, and liquid scintillation counting, which detected the presence of tritium.

"These data can be used to refine and tune glacier flow models, get a better idea of how fast the glacier is melting, predict its future and calibrate ice flow models for greater precision," said Röllin. The methods developed by Spiez Laboratory were validated against IAEA reference samples of water from the Irish Sea to ensure accuracy. Reference samples are used by scientists to check that their testing methods yield accurate results. The IAEA makes such samples available to laboratories worldwide.

"Our tests against the IAEA reference material confirmed our ability to analyse incredibly low radionuclide concentrations in water — a millionth of a millionth of a millionth of a gram per kilogram — something that's quite difficult to do," said Röllin.

Spiez Laboratory presented its research at the International Conference on Environmental Radioactivity (ENVIRA 2021) in Greece in 2021, and at the International Conference on Radionuclide Metrology — Low Level Radioactivity Measurement Techniques (ICRM–LLRMT), 2022, in Italy.

Spiez Laboratory has been an IAEA Collaborating Centre since 2016 and, in 2020, was re-designated as such until 2025, in order to support the IAEA's programmatic activities. As an IAEA Collaborating Centre, it provides training for fellows, and hosts training courses and scientific visitors. It also participates in expert missions to IAEA Member States, to promote the practical application of this technique in other places where glaciers are important for sustainable environmental policy and the economy.

"Spiez Laboratory is a centre of excellence which has a track record of outstanding analytical proficiency, and extensive experience with field sampling and measurements of all types of contaminants, in particular radionuclides," said Iolanda Osvath, Head of the IAEA's Radiometrics Laboratory. "It provides tremendous support for training and methodological development to the IAEA's network of Analytical Laboratories for the Measurement of Environmental Radioactivity (ALMERA). Its research and development addresses a broad range of environmental problems with innovative approaches, as its novel work on glaciers demonstrates."

"Our tests against the IAEA reference material confirmed our ability to analyse incredibly low radionuclide concentrations in water — a millionth of a millionth of a millionth of a gram per kilogram — something that's quite difficult to do."

Stefan Röllin, Researcher at Spiez Laboratory's Nuclear Chemistry Division

Costa Rica leverages nuclear science to improve fertilizer use and measure greenhouse gas emissions

By Andrea Galindo

Agriculture and land use change contribute to about a quarter of the greenhouse gases (GHGs) that cause global warming. One of those gases, nitrous oxide, when released warms the atmosphere 265 times more than carbon dioxide does. Nitrous oxide is released by different biological processes from nitrogen, a nutrient for plants naturally present in soil and added via chemical and organic fertilizers. Applying excessive amounts of fertilizer leads to the release of harmful GHGs into the atmosphere, contributing to climate change.

In Costa Rica, scientists are looking to find the best way to use fertilizers to reduce GHG emissions in rice production, while improving plant productivity and farmers' livelihoods through climate-smart agriculture practices. Together with the IAEA and the Food and Agriculture Organization of the United Nations (FAO), researchers at the country's National Rice Corporation (CONARROZ) and Environmental Pollution Research Centre (CICA) are using isotopic techniques to better understand and establish best practices regarding the use of nitrogen fertilizers in rice plantations.

"A plant needs seventeen types of nutrients, the most important of which is nitrogen," said Mohammed Zaman, a soil scientist at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. Zaman supports the work of the Costa Rican researchers: "It's traditional that farmers use nitrogen fertilizers to improve their crops. However, they may be adding more nitrogen than what a plant can absorb. This not only generates extra emissions of nitrous oxide, but also makes the plant less productive and impacts farmers' income."

CONARROZ and CICA are using isotopic techniques to find out precisely how much fertilizer is needed to optimize rice, when exactly to apply the fertilizer during the rice's life cycle and the ideal chemical composition of fertilizer for rice.

"It's traditional that farmers use nitrogen fertilizers to improve their crops. However, they may be adding more nitrogen than what a plant can absorb. This not only generates extra emissions of nitrous oxide, but also makes the plant less productive and impacts farmers' income."

— Mohammed Zaman, FAO/IAEA Soil Scientist

Researchers in Costa Rica collect samples in a rice field to better understand how farmers can improve fertilizer use and, at the same time, reduce greenhouse gas emissions.
(Photo: A. Pérez/CICA)

Rice farmers participate in an activity organized jointly by CONARROZ and CICA, and the IAEA Collaborating Centre. They learned about agricultural practices for adaptation to, and mitigation of, climate change.
(Photo:A. Pérez/CICA)

"We're looking to find a fertilizer combination that will maximize plant productivity while keeping nitrous oxide and ammonia emissions to a minimum," said Ana Gabriela Pérez Castillo, a researcher at CICA. She said her country needs reliable data on its emissions and that it needs to be able to gather such data by itself. In this connection, she is conducting experiments using the nitrogen-15 isotope technique to trace the movement and origin of nitrous oxide emissions and determine whether they are produced from nitrogen in fertilizers or the soil.

"The data from our experiments will help us and the IAEA produce precise and easy-to-understand instructions for farmers — teaching them that limiting fertilizer use is not only good for the environment, but also for the productivity of their own crops," said Pérez.

Pérez and other researchers at CICA have long employed the nitrogen-15 isotope technique in their efforts to study how to mitigate GHG emissions in agriculture. For this work and many other activities related to the environment, CICA has been an IAEA Collaborating Centre since 2006.

As an IAEA Collaborating Centre, CICA has been transferring its knowledge and expertise on nuclear and isotopic technologies to researchers and experts from other countries. Through its designation with the IAEA, CICA has trained more than 2000 scientists and experts in the region through missions, workshops, e-learning initiatives and webinars on topics related to climate change.

"Thanks to the course, I learned how to measure the carbon footprint of agriculture, particularly of rice production," said Randall Chavarría Rojas, Regional Coordinator of CONARROZ, who took an e-learning course on carbon capture in soil. "It also helped me understand the impact of human activities on global warming, and taught me which actions I can undertake as a rice producer to mitigate the negative impacts on the environment."

As a pioneer of Spanish e-learning courses on isotopic techniques for the environment in Latin America, last year CICA's contract as an IAEA Collaborating Centre was renewed up to 2025. Over the coming years, CICA and the IAEA will continue to implement e-learning activities and four technical cooperation projects in areas related to climate-smart agriculture, GHG measurement and monitoring, and the use of biochar — a black residue made of carbon and ashes that can be used to increase soil fertility and crop production and to sequester carbon from the atmosphere.

Assessing the impacts of climate change and pollution on marine life with nuclear science in Kuwait

By Rakelle Arab and Michael Amdi Madsen

Among the aromatic spices and imported fruit, seafood, such as sea bream, grouper and mullet, is on display at Souk Sharq marketplace. Here, in the heart of Kuwait City, freshly caught fish from the Arabian Gulf has been sold for decades. Like all wet markets, this timeless buyers' and sellers' paradise must deal with the ever-present risk of food contamination. As climate change worsens, concerns have grown about warmer, more acidic waters affecting the growth and health of fish, as well as the way pollutants affect food webs and impact seafood safety. Nuclear methods are a unique tool that researchers can use to find out if these concerns are justified.

"What we're seeing is not all doom and gloom for marine life if the effects of climate change come over a long enough period of time. In our studies we see copepods and shrimp adapt to climate change across generations."

— Saif Uddin, Kuwait Institute for Scientific Research (KISR)

Saif Uddin from the Kuwait Institute for Scientific Research (KISR) is one such researcher. His institute has teamed up with the IAEA to study the effects of greenhouse gas emissions and climate change — such as ocean acidification and warming waters — on marine life using nuclear techniques.

"It's known and understood that climate change impacts marine life, but it's not exactly clear to what extent," said Uddin. "Studying the way certain isotopes are absorbed in animals can give us answers and help authorities better plan how to tackle potential issues." Isotopes of a chemical element can be identified by the number of protons they have. By measuring the ratios of various isotopes of an element in a sample, researchers can study how chemicals and compounds are absorbed by an organism.

With IAEA support, KISR is developing methodologies and establishing techniques for undertaking experiments studying isotopes of copper, mercury and polonium. These metals are of public concern, as they can have serious health effects when they accumulate in high concentrations in the environment and seafood. By studying the metals' isotopes and assimilation rates in the different tissues of marine organisms, KISR experts can trace the origin of these chemicals and so determine the specific cause of contamination. They can also assess how these contaminants move through coastal and marine ecosystems under changing climatic and environmental conditions.

Researcher Saif Uddin is using nuclear techniques to better understand how climate change directly affects growth in marine organisms. (Photo: KISR)

"There are concerns that warmer and more acidic waters might cause marine life to absorb more pollutants, and that they could accumulate in seafood. We used nuclear techniques to find out," said Uddin. Using radiotracers, he found that ocean acidification did not affect polonium uptake in copepods — a subclass of microscopic crustaceans important to the ocean's food web — but said that it could impact the uptake of other metals: "We think ocean acidification could affect the uptake of lead and zinc, as zinc is used in the growth of organisms, but for all other metals we have not seen a noticeable increase in uptake."

Understanding the impact of climate on marine life

Beyond the study of marine pollutants, Uddin said that nuclear techniques also play a key role in our ability to better understand how climate change directly affects growth in marine organisms. In a different study on copepods, Uddin increased the water's acidity and temperature over the course of a year. Uddin found that the copepods were able to adapt to the changing conditions over 14 generations.

In another study, Uddin raised shrimp in increasingly acidic water conditions, similar to those modelled in advanced climate change scenarios. A radiotracer, calcium-45, helped to determine how ocean acidification affects the transparency of shrimp's exoskeletons, an indicator of their health. Uddin found that, while the size of the shrimp did not change between generations, the shrimp were less efficient and consumed twice as much food in order to reach their regular weight.

"What we're seeing is not all doom and gloom for marine life if the effects of climate change come over a long enough period of time. In our studies we see copepods and shrimp adapt to climate change across generations," Uddin said.

Collaborating for the ocean

Uddin's climate change studies started in 2020, but the IAEA has been working closely with KISR for more than ten years. With its expertise in using nuclear techniques to study the environment, the institute is a leading regional research hub and has been designated an IAEA Collaborating Centre for the use of nuclear and isotopic techniques to advance coastal and marine science. More joint projects between KISR and the IAEA are being planned, with a particular focus on collaboration with other countries in the region, and studies exploring the impact of plastic pollution on marine life.

Copepods are a subclass of microscopic crustaceans important to the ocean's food web.
(Photo: Adobe Stock)

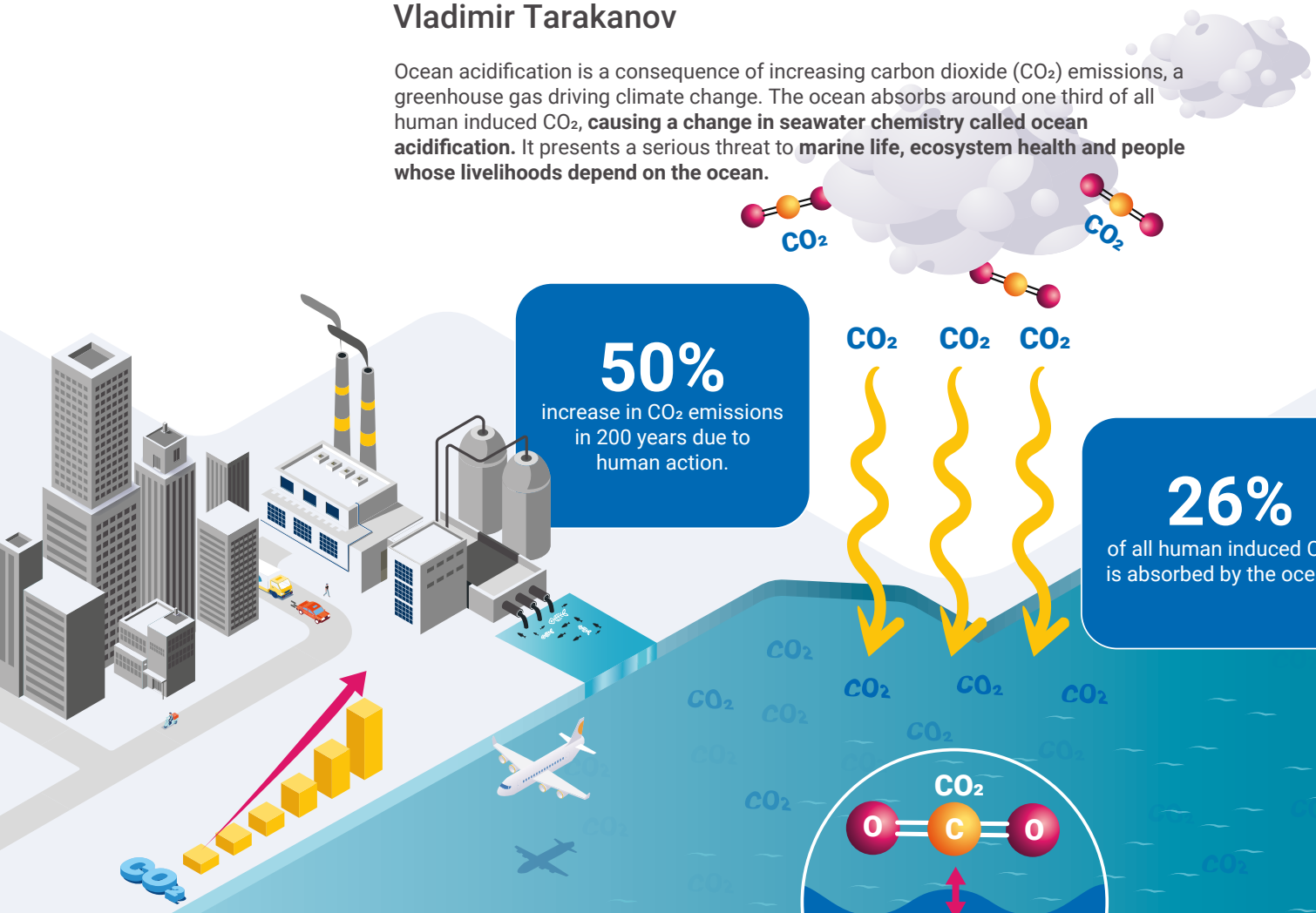
"The warm waters of the Gulf provide one of the most interesting test beds for what is to come in the years ahead as climate change advances," said Marc Metian, a research scientist at the IAEA Marine Environment Laboratories in Monaco. He supports Uddin in coordinating the Collaborating Centre's activities and raising awareness of its findings among other researchers and scientific bodies around the world. "In its region, KISR is a leader in the use of nuclear and isotopic tools for marine research, and globally its findings can help to inform decision makers about how marine life will adapt to warming waters and ocean acidification," Metian said.

As a Collaborating Centre, and through the IAEA's technical cooperation programme, KISR is working to support neighbouring Gulf countries in improving their understanding of marine ecological responses to climate change. The Collaborating Centre is also part of the IAEA's interregional network for collecting high quality ocean acidification data, which is used to support the development of climate change adaptation and mitigation strategies.

How carbon emissions acidify our ocean

Vladimir Tarakanov

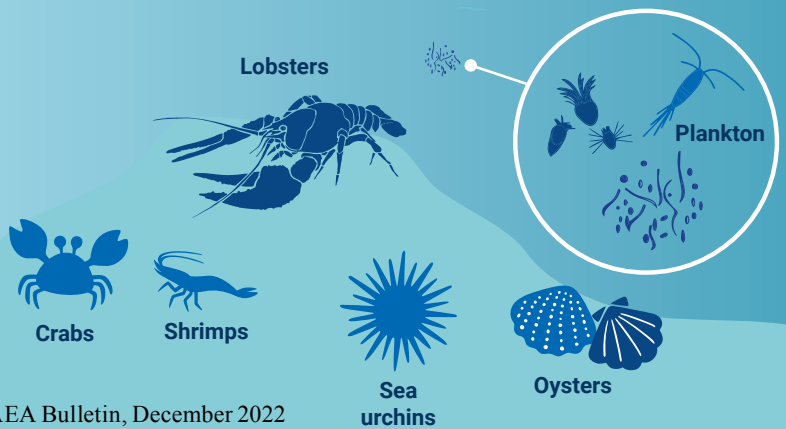
Ocean acidification is a consequence of increasing carbon dioxide (CO_2) emissions, a greenhouse gas driving climate change. The ocean absorbs around one third of all human induced CO_2, **causing a change in seawater chemistry called ocean acidification.** It presents a serious threat to **marine life, ecosystem health and people whose livelihoods depend on the ocean.**



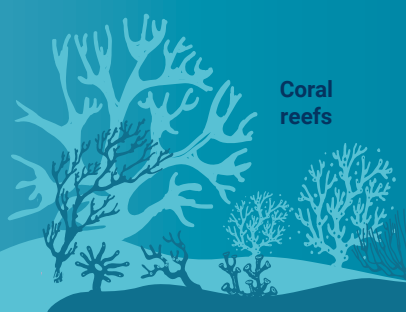
When CO_2 dissolves in seawater, it forms carbonic acid (H_2CO_3), releasing hydrogen ions (H^+) and increasing ocean acidity. Acidity plays a key role in many biological mechanisms, including calcification.

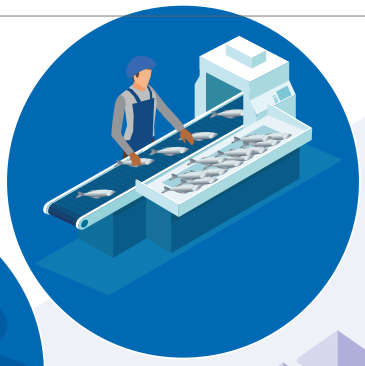
Calcium carbonate ($CaCO_3$) is crucial for organisms which need calcium to develop, build and maintain their shells and skeletons, such as certain types of plankton, oysters, crabs, sea urchins, shrimps and lobsters.

Ocean acidification makes it harder for them to maintain these calcified structures. This can cause disruptions within food chains.

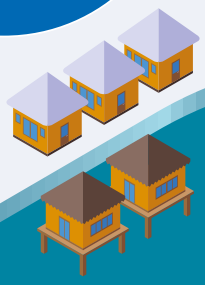


Ocean acidification can also impact the ability of coral reefs to recover from warming and other stressors, by making it harder for corals to build their calcium-based skeletons.





Up to
3 billion people
depend on marine and coastal biodiversity.



Coordinated action on ocean acidification

Ocean acidification impacts both small coastal communities and big industries. By harming aquaculture and tourism, communities that rely on the ocean as a source of food and income will be particularly affected.

It is estimated that up to **three billion people** dependent on marine and coastal biodiversity for their livelihoods could be impacted by ocean acidification. Large shellfish industries are also threatened.

A study in the United States of America found that the country's shellfish industry could lose more than US $400 million annually due to ocean acidification by 2100.

Researchers and industries are exploring solutions to minimize the effect of ocean acidification in oyster hatcheries.

While it is important to develop adaptation solutions, it is also crucial to address the root of the problem — unabated CO_2 emissions from the burning of fossil fuels.

To develop and implement solutions, it is critical to better understand the biological effects of ocean acidification. Nuclear and isotopic techniques, such as radiotracers, can be used as key tools to better understand these processes.

To facilitate this research, as well as to encourage collaboration, coordination and communication regarding international activities on ocean acidification, the **IAEA has established the Ocean Acidification International Coordination Centre (OA-ICC).**

The Centre brings together researchers and organizations from all over the world to focus on scientific capacity building, and outreach and communication activities, in order to promote a science-based approach to decision making in addressing this global problem.

The OA-ICC:

- Organizes **training courses** around the world; provides access to data; and manages a dedicated, open-access website that offers a steady stream of scientific reports, media coverage, policy briefs and other materials on ocean acidification.
- Promotes the development of data portals, standardized methodologies and **best practices**.
- **Raises awareness** among relevant stakeholders and informs them about the role nuclear and isotopic techniques can play in assessing ocean acidification's impacts.
- Supports the Global Ocean Acidification Observing Network (GOA-ON) — a community providing information on ocean acidification monitoring facilities and **access to real-time data.**

Transparency and openness through nuclear law

Enabling climate action

Anthony Wetherall and Chenchen Liang

Nuclear power is, and will be, part of the solution when it comes to climate change mitigation, helping countries achieve their goals and supporting social and economic development in the transition to a global low carbon economy.

Even so, nuclear technology faces unique challenges with regard to public understanding and acceptance, and is not always judged purely on a scientific basis. Meeting climate goals will require a change in public perception, alongside clarification of the scientific facts. Experts project that nuclear power capacity will need to more than double in the coming decades for the world to meet its energy and climate goals. In some countries, perception is already changing. In Germany, for example, a recent survey by Der Spiegel found that 67 per cent of surveyed Germans now favour the continued operation of the country's remaining three nuclear power reactors for the next five years, with 41 per cent of respondents in favour of building new nuclear power plants.

"With the twin crises of climate change and a level of energy insecurity not seen since the 1970s, more countries are considering nuclear power," said Wolfram Tonhauser, Head of the Nuclear and Treaty Law Section in the IAEA's Office of Legal Affairs. He continued, "for many countries, the introduction of nuclear power into the energy mix represents a significant contribution to their climate mitigation objectives, and the success of many of the programmes and projects will depend strongly on openness and transparency to support informed decision making."

Nuclear law for openness and transparency

Nuclear power is a cross-cutting area of nuclear law that is growing in importance as countries decarbonize their energy mix. The principles of openness and transparency are evident and reflected across various areas of nuclear law, both at the national level and in international nuclear legal instruments and their associated mechanisms, processes, arrangements and channels for multilateral State cooperation.

At the international level, for example, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint

Experts project that nuclear power capacity will need to more than double in the coming decades for the world to meet its energy and climate goals.
(Photo: Adobe Stock)

Convention) explicitly recognizes the importance of informing the public about issues regarding the safety of spent fuel and radioactive waste management. During thesiting process for proposed spent fuel and radioactive waste manangement facilities, each Contracting Party must establish and implement procedures to ensure the public availability of information on the facilities' safety. This subject is also addressed by environmental law instruments that intersect with nuclear law, such as the United Nations Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters.

Some of the existing mechanisms and channels are mandatory and periodic, established on the basis of the relevant international legal instruments. For example, there are mandatory national reporting and periodic peer reviews, on safety aspects of nuclear power plants in the context of the Convention on Nuclear Safety (CNS), and on the safe management of spent fuel and radioactive waste, in the context of the Joint Convention. Other mechanisms and channels are voluntary, such as the information exchange processes pursuant to the two legally non-binding IAEA Codes of Conduct, on the safety of research reactors and on the safety and security of radioactive sources.

"At times, the imperative for openness and transparency needs to be reconciled with the need to maintain confidentiality of sensitive information related to nuclear material and facilities, which could otherwise be the target of criminal or intentional unauthorized acts," explained Tonhauser.

National laws and IAEA support

At the national level, exhibiting openness and transparency is one of the five key, interlinked principles of effective stakeholder engagement identified by the IAEA. "While some of the international legal instruments may sometimes be lacking in respect to what is required at the national level in the area of transparency and openness, the gaps are filled by safety standards and other international guidance," Tonhauser added.

National nuclear legal frameworks can provide a foundation for openness and transparency. This is apparent both in the context of informing and consulting interested parties and the public about the possible radiation risks associated with facilities and activities, and about the processes and decisions of the regulatory body; and in the context of public involvement in decision making, in particular stakeholders' right to be heard and involved.

In the Handbook on Nuclear Law: Implementing Legislation, the IAEA sets out model provisions for a comprehensive national nuclear law which build upon the relevant instruments, standards and guidance in the area of openness and transparency, and detail the minimum of what needs to be in the legislation. For example, in the context of power reactors, the model provisions state that, during the review, assessment and licensing processes, regulators must establish procedures for informing and consulting members of the public, including persons residing in the vicinity of a proposed nuclear facility.

"Experience shows that nuclear law-making is not always an easy task," Tonhauser said, "For several reasons, lawmakers, including policy- and decision-makers, legislative drafters, lawyers, regulators and other officials, often need to overcome several hurdles. Parliamentarians also play a critical role, not least by enacting the needed legislation, but they also need to be informed and aware of the many issues."

With these issues and challenges in mind, the IAEA's legislative assistance programme supports nuclear newcomer countries, such as Egypt and the Philippines, in establishing and strengthening their nuclear legal frameworks. The programme also provides training in nuclear law and raises awareness in countries about the importance of adhering to the relevant international legal instruments.

"To support the role that nuclear power can play in the transition to a clean energy future, adequate and comprehensive legal frameworks embracing the principle of openness and transparency are now more critical than ever," Tonhauser said.

"With the twin crises of climate change and a level of energy insecurity not seen since the 1970s, more countries are considering nuclear power."

— Wolfram Tonhauser, Head of the Nuclear and Treaty Law Section in the IAEA's Office of Legal Affairs.

Nuclear in the context of the energy and climate crises

By Miklos Gaspar

World-renowned energy economist and Executive Director of the International Energy Agency (IEA) Fatih Birol is no stranger to nuclear power; in the fight against climate change, he has spoken out in favour of all low emissions options, including nuclear energy. Chair of the World Economic Forum's Energy Advisory Board and featured in Time magazine's 2021 Time 100 list of the world's most influential people, this year Birol delivered a lecture to IAEA country representatives on the global energy crisis and the implications it has for energy markets and climate. We spoke with him to get a better understanding of nuclear energy's role in addressing these two challenges.

Q: You have spoken about a concurrent energy crisis and climate crisis. What role do you see for nuclear power in tackling these?

A: We are seeing today an energy crisis, along with a humanitarian crisis and a climate crisis. They are all interlinked. I believe we are in fact in the first global energy crisis, and this is affecting the oil markets, gas markets, electricity markets and coal markets. The world has never seen such an energy crisis. It's a new energy world with new realities — we are at a turning point for global energy.

I believe that nuclear power can play a role in the countries where it is accepted to address both energy security and climate. To do that, we have to make sure that the nuclear industry delivers on time and on cost, and the safe operation of nuclear power plants is also of crucial importance.

I believe that nuclear power can play a role in the countries where it is accepted to address both energy security and climate. To do that, we have to make sure that the nuclear industry delivers on time and on cost, and the safe operation of nuclear power plants is also of crucial importance.

The 1970s' oil crisis brought economic and social pain, but it also brought innovation — both in increased energy efficiency and a growth in the use of other sources of energy, including nuclear. Over 40 per cent of today's nuclear power plants were built in response to the oil crisis.

The world today has highly competitive energy options to help us overcome the energy crisis: solar, wind, electric cars — as well as nuclear power.

Q: You have said that many countries are "re-appreciating" nuclear energy. Why is that and why is it happening now?

A: Several countries, both advanced economies and developing economies, are considering nuclear. Many countries that had taken nuclear out of their energy options are giving it a second thought. The reason is that they understand that nuclear — if it is operated in a safe manner — can provide support for electricity security and energy security for their countries. Also, nuclear can be one of the options for the energy sector to reduce greenhouse gas emissions, which can help countries reach targets that they have announced. Many governments therefore see nuclear as one of the options — not the only option, but certainly one of the options.

Solar and wind are becoming very cheap, but one of the cheapest sources of electricity in the world is the lifetime extension of existing nuclear power plants.

If, on the other hand, the very justified energy security worries of many countries are met by increased burning of coal, then climate change goals will be out of reach.

Q: In several countries, particularly in the West, a key issue with nuclear power is public opinion. What can organizations like the IEA and the IAEA do to influence attitudes and help ensure that there is an objective view of nuclear?

A: We are not an organization that is either pro- or anti-nuclear. We are an organization that is pro energy security and pro the fight against climate change. We are putting facts on the table. And facts show that, in the absence of nuclear power, it will be much more difficult and costly to reach international climate targets. Another fact we tell governments is that the lifetime extension of existing nuclear power plants is one of the cheapest sources of clean electricity. These are the facts that governments have to tell citizens to gain better public acceptance and overcome difficulties.

There is a change in perception of nuclear power already. People realize that energy security and tackling climate change are important. If we use a lot of renewables and there is a cold winter day with little wind, then we will need other sources of clean electricity like nuclear. Public support and government support is in fact growing — now the nuclear industry has to deliver on cost and on time.

We are an organization that is pro energy security and pro the fight against climate change. We are putting facts on the table. And facts show that, in the absence of nuclear power, it will be much more difficult and costly to reach international climate targets.

Nuclear power can play a role in the countries where it is accepted to address both energy security and climate.
(Photo: Adobe Stock)

IAEA–FAO emergency support helps flood-hit Pakistan with soil fertility and animal diseases

An estimated 33 million people have been affected by floods in Pakistan in 2022.
(Photo: A. Majeed/EU Civil Protection and Humanitarian Aid Operations)

Unusually heavy monsoon rains and rapidly melting glaciers following a severe heat wave this year have led to historic flooding in Pakistan. In August, the country's Government declared a state of emergency and, by the end of that month, a third of the country was underwater. In addition to the tragic loss of human life, there has been mass displacement of people, and the economic damages are estimated to be beyond US $40 billion. Agriculture is particularly vulnerable to natural disasters, such as floods, enduring both short- and long-term consequences, such as harvest and livestock losses, disease outbreaks, and the destruction of rural infrastructure and irrigation systems.

Working together, the IAEA and the Food and Agriculture Organization of the United Nations (FAO) have been in close consultation with Pakistan's Government, the Pakistan Atomic Energy Commission, and leading national agriculture and veterinarian institutes to develop an emergency support package to assist the country in applying nuclear science to better understand the floods' impact on soils, crops and the potential spread of animal and zoonotic diseases. The package consists of scientific equipment, reagents and training.

"The flooding in Pakistan is just the latest impact of unmitigated climate change, and, while it's now too late to stop these floods, it's not too late to stop the situation from getting worse," said Lee Kheng Heng, Head of the Soil and Water Management and Crop Nutrition Section of the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. The IAEA, through its technical cooperation programme, has been coordinating the delivery of equipment to measure the physical and chemical properties of the flooded soils, such as pH, electrical conductivity and nutrient levels, while the Joint FAO/IAEA Centre is providing technical expertise to use the equipment.

Floods are impacting farmers' abilities to sow their seeds and prepare their land for the coming seasons. "Flood waters carry nutrients and sediments that, when deposited on flood plains, can enhance soil fertility. But they can also be washed away downstream," Heng said. "The poor soil aeration in flooded soils can make many soil and plant changes that can adversely influence growth. It's not yet clear how the Pakistani farmlands will be once the flooding recedes. With nuclear techniques, local experts can measure the situation and look to ways to improve its fertility."

Pakistan has a long history of working closely with the IAEA. Its Nuclear Institute for Agriculture and Biology has since 1972 been responsible for the introduction of many food and cash crops using plant mutation breeding — a nuclear technique where seed irradiation helps create spontaneous genetic variations for more productive and climate-resilient crops. Through decades of training and partnerships, the country has also developed expertise in measuring soil fertility, but it lacks equipment for dealing with a crisis of this scale.

The risk of animal diseases

The crisis has also affected the care of livestock, which has been displaced by the flooding. Carla Bravo de Rueda, an Animal Health Technical Officer at the Joint Centre, highlighted the impact this could have on the spread of animal and zoonotic diseases. "Animal movement and the increase of contact between mixed animal populations represent a risk for the transmission of animal and zoonotic diseases," she said. "Veterinarian laboratories and authorities need greater capabilities to diagnose and control animal diseases, identifying outbreaks before they get out of control."

The Joint FAO/IAEA Centre is sending molecular and serological diagnostic tools to Pakistan to test for diseases such as foot-and-mouth disease (FMD), lumpy skin disease (LSD) and peste des petits ruminants (PPR) — all of which are pre-existing endemic risks in the country. Additionally, the Joint Centre is evaluating a strategy with the Pakistani veterinarian authorities for possible vaccination of some animals to protect them from diseases, thereby preventing future outbreaks.

"We're in a situation where immune-challenged animals could be exposed to life-threatening diseases," explained Bravo de Rueda. "At the same time, the shelters for these animals are flooded and the lands from which they eat are below water. This animal crisis could become another human crisis, as people depend on their livestock for food and income."

Through a technical cooperation project with Pakistan on the topic of agriculture, which began this year and will run until 2025, the IAEA will continue providing support to the country in enhancing its human and technical capacities for ensuring food security, including food safety and climate resilience in the mid-to-long term.

"The international community should stand in solidarity in the face of such a climate change-driven catastrophe," said Jane Gerardo-Abaya, Director of the Division for Asia and the Pacific of the IAEA's Department of Technical Cooperation. She explained that the IAEA has a strong partnership with the Government of Pakistan and is now ramping up its rapid recovery and resilience-building support through its technical cooperation programme and the Joint FAO/IAEA Centre.

— By Michael Amdi Madsen

IAEA builds nuclear security detection capabilities by training instructors for front line officers

Front line officers are positioned at strategic locations where illegal acts — such as smuggling of drugs, human trafficking, and illicit trafficking of nuclear and other radioactive material — could be encountered. Ensuring they have a full understanding of the threats posed by criminal acts or unauthorized acts involving nuclear and other radioactive material out of regulatory control is an important component of a country's nuclear security detection architecture.

"Front line officers are potentially first alerted about nuclear and other radioactive material out of regulatory control through information alerts or detection equipment alarms," said Daming Liu, Head of the IAEA's Nuclear Security of Materials Outside of Regulatory Control Section. "A specific training programme that involves instructors in nuclear security detection is an essential part for the sustainable capacity building of front line officers."

From 2011 to 2015, the IAEA trained over 400 instructors from 32 countries

Enhancing the capabilities of front line officers is instrumental to ensuring the detection of, and response to, nuclear security threats.
(Photo: D. Calma/IAEA)

The training course for instructors of front line officers covers activities to reinforce learning objectives that include goodpractices to enhance nuclear security.
(Photo: M. Tremonte/IAEA)

as trainers of front line officers on responsibilities in nuclear security detection operations.

Recognizing the need for a consistent global approach, the curriculum has evolved in collaboration with the US Department of Energy's Office of Nuclear Smuggling Detection and Deterrence (NSDD) and the Joint Research Centre (JRC) of the European Union, through the Border Monitoring Working Group (BMWG). The revised curriculum was piloted in 2017 and first implemented in 2018. The curriculum builds training development and instruction capabilities in general, as well as instructors' capabilities for training front line officers in nuclear security detection. To date, 62 instructors from 21 countries have been trained through 4 such training courses.

The course aims to improve participants' instruction skills and to prepare them to competently deliver a technical curriculum on detection of nuclear and other radioactive material out of regulatory control. The two-week course involves lectures focused on building a common understanding around instructional good practices for adult learners, and includes a 'teach back' segment. Participants are then able to deliver the course in their countries.

Past trainees are now instructors

Instructors from Malaysia, Nigeria and the United States of America participated in the implementation of this curriculum during an IAEA regional training course in August 2022.

"The training provided an understanding of the importance of security for nuclear and other radioactive material out of regulatory control and the role front line officers play in countering threats. Capacity building of front line officers through a systematic approach to training can never be overemphasized, as it gives a firm foundation for the implementation of Integrated Nuclear Security Support Plans at the national level," said Walter Kamusasa, an inspector at the Radiation Protection Authority of Zimbabwe, who was a trainee at the course.

Luzza Lenny binti Shahbudin, Assistant Commissioner of Police within the Police Leadership Excellence Unit of the Royal Malaysia Police College Kuala Lumpur, has been an instructor since 2018. "In the train the trainers course we work as a team," she said. "Future men and women instructors work on essential skills to successfully deliver the technical front line officer curriculum." For example, in the August 2022 course, two Nigerian instructors had been trainees in past courses led by Shahbudin.

Future training opportunities

The IAEA continues to collaborate with instructors who have taken the course to understand how the curriculum is implemented in their countries.

Countries interested in designating participants for future courses are required to have developed a national detection strategy as part of their nuclear security plans, and to have included in their national Integrated Nuclear Security Support Plan the need for instructors in this subject area.

The next train the trainers course for instructors of front line officers on the detection of nuclear and other radioactive material out of regulatory control is being planned for 2023.

The IAEA provides additional opportunities for front line officers to collaborate through the Front Line Officer Network (FLO Network). The third Annual Meeting of the Network was held in Vienna from 11 to 13 October 2022. Questions regarding the FLO Network and its activities can be directed to the FLO Network.

— By Matthew Tremonte

Chad and Senegal reach key milestones in Rays of Hope initiative and cancer control planning

IAEA Director General Rafael Grossi officially launched the Rays of Hope initiative during a side event at the African Union Summit in February 2022.
(Photo: IAEA)

Chad and Senegal are two of the eight pioneer countries of Rays of Hope, an IAEA initiative to increase access to radiotherapy for cancer patients in low and middle income countries. Nine months into the initiative, Chad is making preparations for its first cancer therapy centre in N'Djamena and plans to launch its National Cancer Control Plan (NCCP) in early 2023, while Senegal has recently completed development of its NCCP, detailing an ambitious national objective to scale up cancer care outside Dakar, in particular increasing access in Diamniadio.

Improving access to cancer care in Senegal

Today, there are four operational linear accelerators — the machine most commonly used to deliver radiotherapy to cancer patients — in Senegal, each of which has a capacity to treat approximately 30 patients a day under normal conditions. The country is also expanding its nuclear medicine services, with a plan to serve other countries in the West Africa region. The IAEA has supported Senegal in the evolution of its cancer care programme, including upgrading from 2D to 3D radiotherapy and brachytherapy in 2019, which offers the benefit of producing more individualized patient treatment, better clinical outcomes and reduced side effects.

In May 2022, at an event marking a pivotal milestone for Senegal, more than 50 national professionals from hospitals, public administration and civil society participated in the official validation of the country's NCCP for 2022–2025, alongside IAEA officials and international experts in cancer control.

"The development and adoption of this new NCCP allows the Government of Senegal to identify the priorities for cancer prevention and control," said Babacar Gueye, Director of the Senegalese Ministry of Health and Social Action's Directorate for Disease Control. "In particular, this plan will guide us in allocating the necessary resources to reactivate the cancer registry and to advance the decentralization of radiotherapy services. Furthermore, by defining the baseline and the targets for the next five years, we will be able to monitor and evaluate the progress of our capacity to scale up the access to cancer diagnosis and treatment to the whole country."

Through the Rays of Hope initiative, the IAEA has provided technical advice to reinforce the cancer control programmes of these countries, where the two most common cancers are breast cancer and cervical cancer, with the support of the World Health Organization (WHO) and the International Agency for Research on Cancer (IARC).

Decentralizing cancer care in Chad

In 2020, following the development of a bankable document with IAEA assistance to describe Chad's planned activities to potential donors, over €20 million was mobilized by the Kuwait Fund for Arab Economic Development in support of Chad's cancer control activities. The funds will be used to construct the first public centre for the treatment and control of cancer in N'Djamena, the national capital.

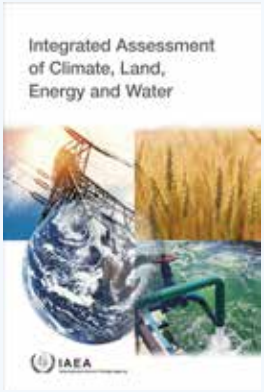
"The Rays of Hope initiative provides a concrete step for our country towards a long-term investment strategy," said Fatima Haggar, National Coordinator of the Chadian Ministry of Public Health's programme on cancer. "This perspective will allow the Government to develop a set of milestones to be achieved during the next 10 to 15 years to ensure the whole population of Chad has equal access to diagnosis and treatment services."

Chad's NCCP for the 2022–2026 period includes the development of capacity building programmes in medical oncology, radiation oncology and surgical oncology for all categories of staff — including physicians, technologists, medical physicists and nurses — and the construction of the first cancer centre in the Ndjamena region.

"As we all know, a stand-alone initiative cannot tackle the cancer burden," Haggar said. "We must ensure a comprehensive strategy to address the whole continuum of cancer, from prevention to palliative care."

For Chad and Senegal, as well as other countries in need of increased access to radiotherapy for cancer patients, Rays of Hope is already starting to build on the IAEA's long-standing support in health care where it most needed.

— By Thuloane Tsehlo and Giovanni Saporiti



INTEGRATED ASSESSMENT OF CLIMATE, LAND, ENERGY AND WATER

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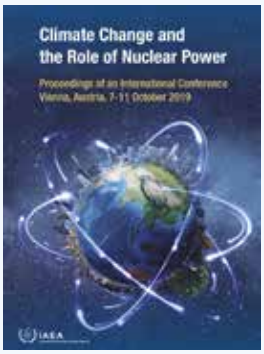

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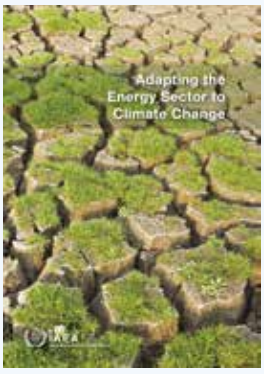

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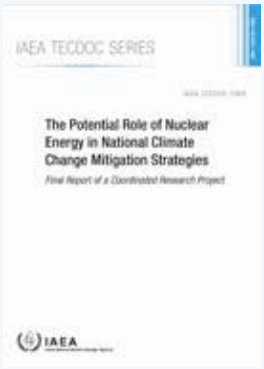

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