IAEA BULLETIN
INTERNATIONAL ATOMIC ENERGY AGENCY
June 2015 • www.iaea.org/bulletin

Climate Change

Making a difference through nuclear technologies

Also inside:
IAEA News

IAEA BULLETIN
is produced by the
Office of Public Information
and Communication (OPIC)
International Atomic Energy Agency
PO Box 100, 1400 Vienna, Austria
Phone: (43-1) 2600-21270
Fax: (43-1) 2600-29610
iaeabulletin@iaea.org

Editor: Miklos Gaspar
Managing Editor: Aabha Dixit
Contributing Editor: Nicole Jawerth
Design & Production: Ritu Kenn

IAEA BULLETIN is available
› online at **www.iaea.org/bulletin**
› as an App at **www.iaea.org/bulletinapp**

Cover:
Nuclear science can play a significant role in both climate change mitigation and adaptation.
(Design: Ritu Kenn)

Read this edition on the iPad

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 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.

Combating climate change: how nuclear science and technology are making a difference

By Yukiya Amano, Director General, IAEA

Climate change is the biggest environmental challenge of our time. As governments around the world prepare to negotiate a legally binding, universal agreement on climate at the United Nations Climate Change Conference in Paris at the end of the year, it is important that the contributions that nuclear science and technology can make to combating climate change are recognized.

Nuclear science, including nuclear power, can play a significant role in both climate change mitigation and adaptation.

Mitigation

Nuclear power, along with wind and hydro, is one of the lowest-carbon technologies available to generate electricity. According to the latest World Energy Outlook statistics, the use of nuclear power has already prevented the release of around 56 gigatonnes of carbon dioxide since 1971, equivalent to two years of global emissions at current rates. This is a very significant achievement, and shows the potential of nuclear power in climate change mitigation.

The IAEA works to increase global awareness of the role of nuclear power in relation to climate change, in particular by trying to ensure that the role that nuclear power can and does play in assisting countries to reduce their greenhouse gas emissions is properly recognized.

In line with its mandate, the IAEA will continue to help countries to use nuclear technology in a safe, secure and environmentally friendly manner.

Adaptation

Despite mitigation measures that have been implemented in a number of countries, global warming is already a reality which is having serious consequences in many parts of the planet.

As the articles in this edition of the *IAEA Bulletin* demonstrate, nuclear science and technology can play a vital role in assisting countries to adapt to the consequences of climate change. Better flood control in the Philippines, the development of new watering techniques in increasingly arid regions of Kenya, new technologies to measure the impact of climate change in Antarctica — these are just some of the areas where support from the IAEA is making a real difference.

Scientific progress is heavily dependent on the brilliance and passion of committed individuals. We are proud of the work of the scientists who, with the help of the IAEA, are developing new varieties of plants more suited to the changing climatic conditions of their countries. The work of IAEA fellows in Afghanistan, Mauritius and Pakistan, whom we profile in this issue, improves the lives of farmers whose livelihoods and food security would otherwise be threatened by the effects of climate change.

As these examples demonstrate, nuclear science and technology are making major contributions to sustainable development around the world. It is my hope that participants in the Paris climate talks will recognize their value.

"Nuclear science, including nuclear power, can play a significant role in both climate change mitigation and adaptation."

— Yukiya Amano, Director General, IAEA

(Photos: C.Brady/IAEA)

World View

From Inside the IAEA

IAEA News

stories

Nuclear power forms an important pillar of many countries' climate change mitigation strategies

By Miklos Gaspar

"Climate change is a common challenge faced by all nations, and it is important that the international community joins together to combat this challenge."

— Ambassador Jingye Cheng, China's Permanent Representative to the United Nations and Other International Organizations

The need for climate change mitigation is a salient reason for an increasing number of countries considering nuclear power within their national energy portfolios, according to IAEA experts and government sources.

"Concerns about climate change is one of the drivers for countries to introduce or to expand their use of nuclear power," said David Shropshire, Head of the IAEA's Planning and Economic Studies Section. Other factors include growing energy demands and the desire to increase energy security and reduce dependence on volatile fossil fuel costs, he added.

Nuclear power plant under construction in China.
(Photo: C. Brady/IAEA)

New nuclear power stations will help the United Kingdom reduce its greenhouse gas emissions by 80% by 2050 and secure its energy supply, according to the UK Government's policy paper *2010 to 2015 Government Policy: Low Carbon Technologies*. "Nuclear power is low carbon, affordable, dependable, safe and capable of increasing the diversity of energy supply," the paper says. France has the fourth-lowest carbon dioxide (CO_2) emission rate per GDP among Member countries of the Organization for Cooperation and Development (OECD) "thanks to its fleet of nuclear power plants," says the French Government's sustainable energy policy paper.

Nuclear power has saved the release of an estimated 56 gigatonnes of CO_2 since 1971, or close to two years of global emissions at current rates, according to the International Energy Agency's latest *World Energy Outlook*. By 2040, nuclear energy will have prevented the release of four years' worth of CO_2 emissions.

Nuclear power is a key part of China's clean energy plan

Increasing the capacity and share of nuclear power in its energy mix is one way that will help China meet its pledge to reduce greenhouse gas emissions after 2030. China, which alone accounts for over a third of nuclear power reactors under construction around the world, sees nuclear power as a clean source of energy that will help combat both global and local environmental problems, while contributing to the country's growing economy, said Ambassador Jingye Cheng, China's Permanent Representative to the United Nations and Other International Organizations in Vienna.

"Climate change is a common challenge faced by all nations, and it is important that the international community joins together to combat this challenge," said Cheng, who is China's ambassador to the IAEA. "China will do its part, and nuclear energy is part of the solution."

Making its economy more energy efficient and increasing the share of renewable energy sources are other important parts of China's climate change mitigation plans, he added.

"While for the time being still relying on fossil fuel sources, we are putting more emphasis on the development of low-carbon resources," Cheng said. The country's National Energy Development Strategy Action Plan set a 15% target for non-fossil energy sources by 2020, compared with just under 10% at the end of 2013.

China has 23 nuclear power reactors in operation, 27 under construction and several more about to start construction. Additional

reactors are planned, including some of the world's most advanced, to provide more than a three-fold increase in nuclear capacity to 58 gigawatts by 2020. The reactors under construction will have a combined capacity of 30 gigawatts.

China is facing a grave ecological situation and is taking steps to address climate change, Cheng explained. Its national plan on climate change includes the establishment of a carbon emission trading market, as well as deepening international cooperation on the reduction of greenhouse gas emissions under the principle of 'common but differentiated responsibilities'. In its nuclear energy expansion plans, the country is focusing on the construction of large pressurized water reactors and the development and piloting of high temperature gas cooled reactors and fast reactors, Cheng said.

China's track record in the safe and secure operation of its nuclear power plants and the piloting of its new, third generation reactor design position it as a global player in nuclear technology, Cheng said. "We stand ready to share our expertise and technology with, and provide financial support to, newcomer and expanding countries."

Julie Sadler also contributed to this article.

What is climate change?

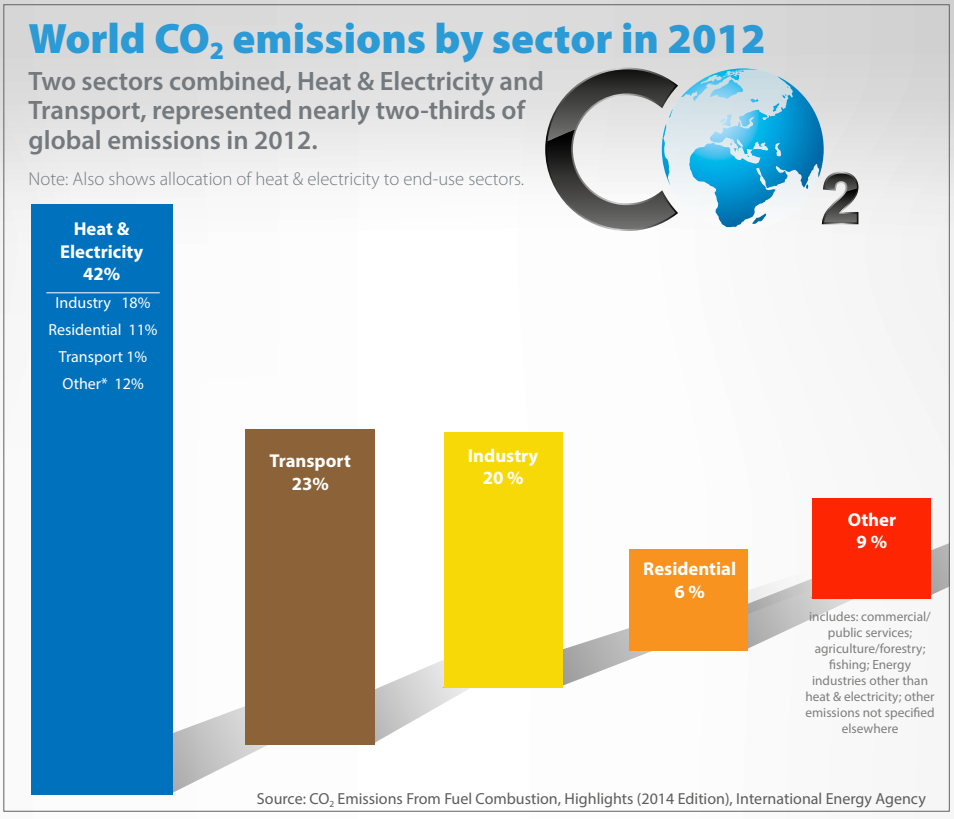
Climate change is a topic everyone is talking about, but what is it and why is it happening now?

It's important first to note that the Earth's climate is always changing; global average temperatures and weather patterns fluctuate yearly, but over great periods of time scientists can identify and examine climatic trends. In the past, changes in climate have been attributed to solar activity, plate tectonics, volcanic activity and even biotic processes. However, the current climate change that's being reported in the media is not related to these natural processes. What's happening is 'anthropogenic climate change', or human-caused climate change, a phenomenon that's been in the making since the industrial revolution.[1]

The factors involved in anthropogenic climate change are varied, but the world's most authoritative voice on the topic, the United Nations Intergovernmental Panel on Climate Change, has stated that greenhouse gases, particularly carbon dioxide (CO_2), are the major cause. CO_2 is a gas, a chemical compound that's released when fossil fuels like coal, oil, and natural gas are burned. Plants absorb CO_2 during photosynthesis, but the current rate of emissions exceeds the capacity of plants and other 'carbon sinks'[2] to remove CO_2 from the atmosphere.

Since 1900 the global average temperature has risen by 0.7 degrees Celsius, and the effects of climate change are already occurring. Some of the expected and observed impacts of CO_2 emissions and climate change include: changing precipitation patterns; shrinking glaciers; Greenland and Antarctic ice sheet mass loss; decreasing Arctic sea-ice extent; thawing of permafrost; natural disasters like heat waves, droughts, floods, cyclones, and wildfires; and ocean acidification.

[1] IPCC, 2014. Climate Change 2014: Synthesis Report, Summary for Policymakers, www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf.
[2] Carbon sinks are reservoirs that accumulate and store carbon-containing chemical compounds for an indefinite period, and include oceans, forests and soils.



Trained to adapt: researchers from Pakistan, Mauritius and Afghanistan breed mutant plants to take on a changing climate

By Nicole Jawerth

From cotton in Pakistan to tomatoes in Mauritius and wheat in Afghanistan, many crops around the world are being devastated by erratic rains, droughts, diseases and relentless heat, which are being exacerbated by climate change. As the global search for solutions to climate challenges continues, three researchers are using their training with the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture to develop new plant breeds that can withstand these adverse conditions and help keep their countries' crops growing strong.

Cotton in Pakistan

"Climate change is causing major damage to crops in Pakistan, and having serious adverse effects on growth, maturity and productivity of cotton plants and the lives of farmers," said Mehboob-ur Rahman, Principal Scientist and Group Leader of the Plant Genomics and Molecular Breeding Laboratory at the National Institute for Biotechnology and Genetic Engineering, Pakistan Atomic Energy Commission. "I am using my training towards different projects for developing new plant variations, including mutant populations of cotton and wheat that tolerate higher temperatures, and are more resistant to diseases. So far, my group has developed seven cotton varieties." Cotton is one of the most important cash crops for Pakistan and a major source of foreign exchange. With more than 70 per cent of the population living in rural areas, it is also a significant source of livelihood for many people.

Mehboob-ur Rahman, Principal Scientist, Pakistan Atomic Energy Commission (left), and Bradley Till, Technical Officer, FAO/IAEA Plant Breeding and Genetics Laboratory (right).
(Photo: A. Qaiser Khan/Pakistan Atomic Energy Commission)

Rahman trained twice at the Plant Breeding and Genetics Laboratory, one of five laboratories that make up the Joint FAO/IAEA Agriculture and Biotechnology Laboratories at Seibersdorf, Austria, first in June 2012 and then in February 2013. He learned how to create new plant varieties using mutation breeding (see box on page 13) and worked closely with IAEA experts and scientists from around the world.

"Before my training, I had never been exposed to such kind of research work, and I found it most fascinating for creating novel plant variations within a limited time period. It shows that this tool can work better compared to the conventional breeding tools," said Rahman. "In addition to the training, we also developed a working relationship with the IAEA technical officer, and we now usually seek guidance from him for arranging new experiments."

Rahman is now working with a team at the Institute through an IAEA technical cooperation project, applying his skills to developing new cotton and wheat plant varieties resistant to environmental stresses and diseases like cotton leaf curl disease — a virus that can cause stunting and drastically reduced cotton plant yields.

"Every year, I create mutant lines of cotton and wheat crop," said Rahman. "Once these mutant lines are tested further, the best ones will be selected for multiplication and after their release, distributed to the farmers." The new mutant lines are expected to be available in 2016 to 2017 for testing at various farms and will help to maintain yields and improve the socioeconomic conditions of the rural community, he said.

Tomatoes in Mauritius

"The heavy rainfalls interrupt certain socioeconomic activities, schools and the tourist industries, and they affect the agricultural sector, damaging many plantations. And the increase in temperature affects cropping patterns, flowering and productivity of some vegetables and fruits. This has had a direct effect on the flowering stage of tomatoes, which causes flower drop that leads to decreases in fruit production and eventually a reduction in yields," said Saraye Banumaty, Senior Research Scientist at the Food and Agricultural Research and Extension Institute in Mauritius. "The mutation breeding programme for tomatoes is addressing the climate problem by breeding a heat-tolerant tomato line that will hopefully adapt to the rising temperatures."

Banumaty is using her training at the FAO/IAEA laboratories in 2011 and 2014–2015 to help her to advance her research, she said. "Both training courses have broadened my knowledge of the use of mutation induction using nuclear and other techniques for crop improvement. Moreover, I was able to understand and make use of biotechnology for detection of mutants. I also participated in the development and making use of a low-cost method for the characterization of mutants," she said. "The training I received from the IAEA has helped to improve my capabilities to undertake research here at home."

The new mutant tomato plants are still under evaluation and development through an IAEA-funded project, but preliminary results show that some mutant lines are showing tolerance to heat stress. The variety is expected to be released for distribution by late 2016 and "will help improve the tomato production locally especially during summer months," said Banumaty. "This will increase the revenue of small growers, and there will be a greater supply of tomatoes on the local market at a reasonable price."

Saraye Banumaty, Senior Research Scientist, Food and Agricultural Research and Extension Institute, Mauritius
(Photo: D. Ndeye Fatou)

Wheat in Afghanistan

"An average Afghan farmer owns one hectare of land, and an average Afghan family has seven members, so with 50 000 hectares of land cultivated with the new wheat seed variety I developed after my IAEA training, the plants' higher yields and resistance to diseases have been benefiting 350 000 people," said Sekander Hussaini, Head of the Chemistry, Biology and Agriculture Research Centre of the Academy of Sciences of Afghanistan. "Picking mutations that fit the climate and using the new varieties are very important for Afghanistan and for farmers' livelihoods. Over 70 per cent of Afghans depend on agriculture and related agribusiness, so having plants with good yields and resistance to diseases and that are able to thrive in the changing climate is very important."

Hussaini learned how to use nuclear techniques for plant mutation breeding through training at the FAO/IAEA laboratories in 1992. He returned to the laboratories in 2012, where he trained with the Agriculture and Biotechnology Laboratory, as well as the Plant Breeding and Genetics Laboratory.

"This training helped me to learn radiation techniques for plant breeding and to identify the best variety of wheat that is suitable for the Afghan climate and soil," said Hussaini. Many of Hussaini's seed varieties have already been successfully used by farmers in several provinces of Afghanistan. This and other areas of Hussaini's work in plant breeding earned him a 2014 FAO/IAEA Achievement Award in plant mutation breeding and a nomination for the World Food Prize in 2012–2014.

He is now working on a new series of wheat seeds that are still under evaluation, but he expects good results. "Six experimental varieties were selected because they are better than others, their yield is more than twice that of their parents and they are more disease resistant too," he said. "Now we are studying and researching the next generation of these seeds for the future to see how we can make them better."

Sekander Hussaini, Head, Chemistry, Biology and Agriculture Research Centre, Academy of Sciences, Afghanistan
(Photo: FAO/IAEA)

Greening Kenya's drylands through climate-smart agriculture

By Rodolfo Quevenco

Climate-smart agricultural practices can help turn marginal lands into productive fields.
(Photo: D. Calma/IAEA)

"The use of nuclear techniques to validate water and nutrient management technologies is essential for Kenya to realize its vision of developing a modern and productive farm and livestock sector."

— Isaya Sijali, Kenya Agricultural and Livestock Research Organization

Arid and semi-arid lands account for almost 80 per cent of Kenya's land area, and climate change is threatening this fragile ecosystem.

In a country where suboptimal agricultural practices already result in poor crop growth, low vegetative cover, low crop yields and serious land degradation, weather conditions resulting from climate change and variability have made drought and water scarcity common.

Using nuclear techniques, the IAEA is helping Kenya improve soil fertility and water management technologies, as part of the introduction of Integrated Soil Fertility Management (see box), which can help maintain the right water, nutrient and carbon balance and maximize climate change adaptation in agricultural systems.

Finding the right balance

Under an ongoing five-year project, the IAEA is working with local laboratories and scientists to determine the extent of carbon loss from the soil and the effects of drought on plants and water resources in the arid and semi-arid regions of Kenya. It is also helping to measure fertilizer intake and water use, as well as the rate of evaporation. Data from field tests will be fed into various models to generate recommendations for the appropriate farming systems to introduce in the affected regions.

For example, more than 300 farmers were trained in terracing techniques that are used to conserve soil and water and improve productivity. Most of them have been able to adopt the techniques and have since obtained good yields, said Isaya Sijali, a principal research scientist and coordinator of irrigation, drainage and problem soils management at the Kenya Agricultural and Livestock Research Organization. Many are now able to harvest over 10 tonnes of fodder per hectare from land that lay barren before the project's inception.

The IAEA is also providing equipment and experts to support the project. To facilitate the transfer of knowledge to local counterparts, it has provided several fellowships and scientific visits, as well as fellowship training.

A key goal is to combat land degradation caused by overgrazing and poor soil

management practices. The project also aims to boost agricultural production, Sijali said.

"The use of nuclear techniques to validate water and nutrient management technologies is essential for Kenya to realize its vision of developing a modern and productive farm and livestock sector," Sijali said.

"The technologies will help us to maximize the use of high- and medium-potential lands and to further develop arid and semi-arid areas for both crops and livestock production," Sijali added. "Nuclear techniques will also help us to quickly adapt our use of these lands to better cope with the effects of climate change."

Almost 80 per cent of Kenya's land area is composed of arid and semi-arid lands.
(Photo: R. Quevenco/IAEA)

Multi-agency collaboration

The International Institute for Applied Systems Analysis (IIASA) in Vienna, Austria, has also collaborated on the project. Experts from IIASA are working with counterparts in Kenya and the IAEA, assessing the water footprint of crops in the Central, Eastern and Rift Valley counties. This is expected to yield valuable data on how much water consumption is related to rainfall and how much to the availability of surface or groundwater.

The water availability assessments — concerning abundance, need and/or scarcity — will in turn lead to a better understanding of the impact of drought on existing resources and on the communities in these areas.

A notable extension to the project is the planned development of mobile-based technology for sharing information with farmers. Once in place, practical information, such as how much fertilizer to use and when and how often to irrigate, can be sent to farmers straight from a mobile phone.

Climate-smart agriculture

The catchphrase most often used to describe this integrated, adaptive agricultural model is 'climate-smart agriculture'.

"We may not be able to totally stop the ravaging effects of drought but we could minimize them through employing farming methods that adapt to changing climatic conditions and boost productivity while maintaining the sustainability of natural resources," Sijali said.

"By supporting farmers and empowering them to use sustainable land management practices, we are helping them contribute to a positive ecosystem and maintain the right water, nutrient and carbon balance and therefore a better quality of life for all."

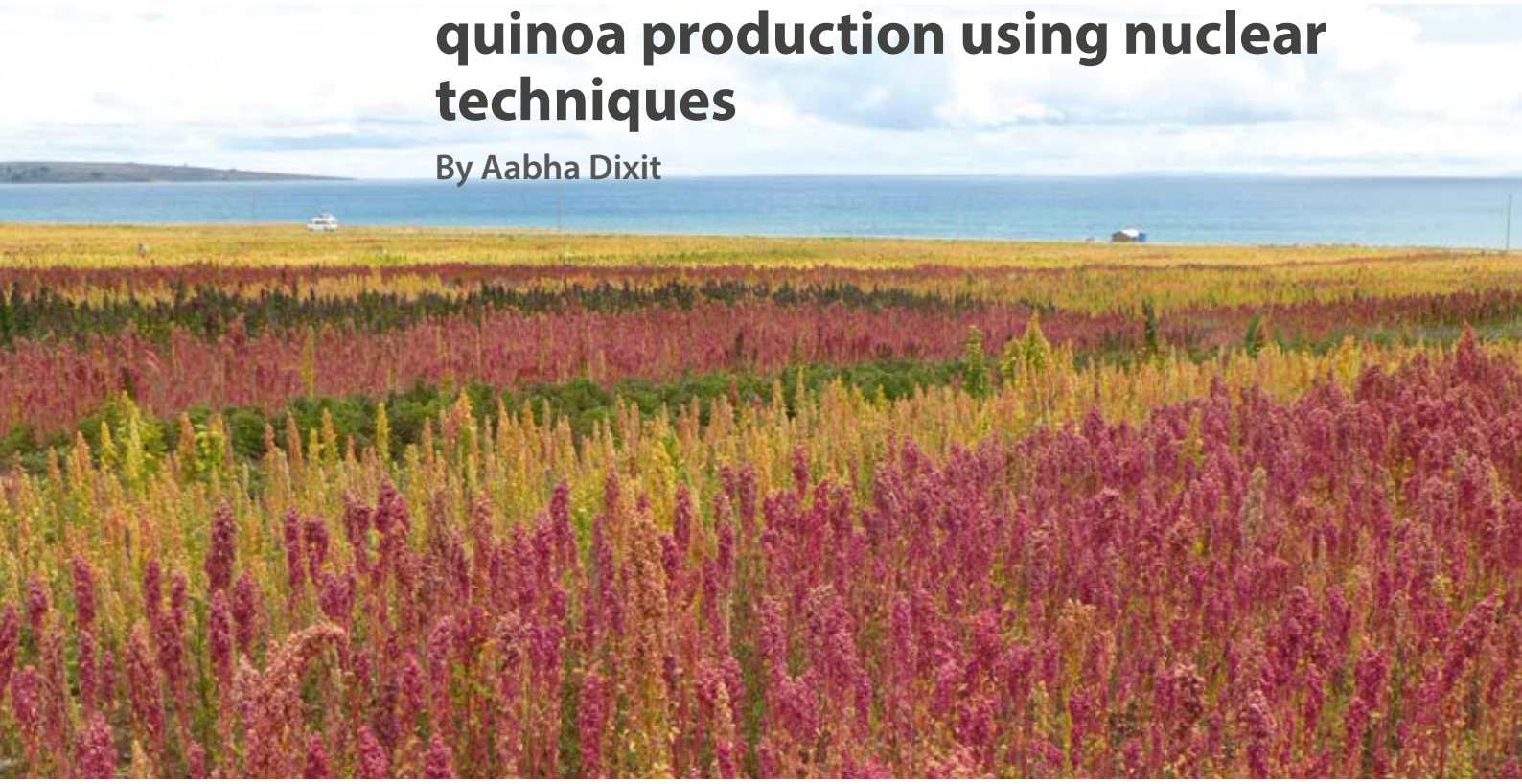
THE SCIENCE

Integrated Soil Fertility Management

Field trials have been established in different parts of Kenya to identify integrated best practices, combining the principles of Integrated Soil Fertility Management (ISFM), conservation agriculture and water management. The results have shown that in the arid and semi-arid eastern part of Kenya, technology packages, which include the use of tiered-ridging for water conservation, improved crop varieties, use of manure and micro-dosing, among other ISFM technologies, were able to increase maize yields from less than 500 kilograms per hectare to an average of 1.2 tonnes per hectare.

Climate change adaptation: boosting quinoa production using nuclear techniques

By Aabha Dixit



Field with quinoa mutant lines.
(Photo: L. Gomez-Pando/ National Agrarian University of La Molina, Peru)

"Due to its high nutritional, agronomic and economic value, quinoa is set to be a major food for future generations and an important alternative crop considering the challenges caused by climate change"

— Qu Liang, Director, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

In the battle to help developing countries overcome threats from declining food production caused by climate change, one species of edible grain-like crop has caught international attention because of its unique nutritional value. New and improved varieties of quinoa, historically grown in the highlands of South America, will be made available to farmers in mutations adapted to challenging environments in Bolivia and Peru.

Increased genetic diversity is the result of the use of nuclear techniques (see box) in collaboration with the IAEA and the Food and Agriculture Organization of the United Nations (FAO), said L. Gomez-Pando, Principal Professor and Head of the Cereals and Native Grains Research programme at the National Agrarian University of La Molina in Peru. "There are 64 mutant lines of quinoa selected by yield potential and quality for the market," he said. "These mutant lines will be further evaluated and the best lines will be released as new varieties in 2015–2016."

The use of new and high-yielding quinoa varieties will allow farmers to improve their income and increase their own protein intake, Gomez-Pando explained. The new varieties will provide seeds at affordable prices to people in danger of malnutrition, especially children below five years of age.

"Due to its high nutritional, agronomic and economic value, quinoa is set to be a major food for future generations and an important alternative crop, considering the challenges caused by climate change," said Qu Liang, Director of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Quinoa is now considered to be essential in efforts to tackle hunger, malnutrition and poverty.

Protecting and enhancing quinoa production using nuclear techniques

The Joint Division used advanced nuclear techniques to enable farmers in Latin America and elsewhere to further boost quinoa production. This was achieved through induced mutation and the detection of improved quinoa genotypes, which has resulted in the breeding of new quinoa varieties.

Quinoa has exceptional nutritional composition, with higher protein content than brown rice, barley and millet. Besides being gluten free, quinoa is an excellent source of dietary fibre and has elevated levels of

phosphorus, magnesium, iron and calcium. It is also rich in vitamins.

Global interest in quinoa farming

Quinoa is cultivated in the Andean region, from Colombia in the north, to Argentina and Chile in the south. It is planted mainly at elevations of between 3000 and 4000 metres, where hostile climatic conditions thwart the growth of other crops. The key producing nations are Bolivia, Peru and Ecuador. Farmers in the United States of America, France, England, Sweden, Denmark, Holland and Italy, as well as Morocco, Egypt, Kenya and the northern regions of India, have also begun cultivating the crop, with increasing success.

The recognition of the value of quinoa has transformed it from a neglected crop to one in high international demand. Various quinoa varieties have been developed to be tolerant to salt, drought or frost and these attributes have created wider global interest in its cultivation. There are valuable genetic resources that can be obtained by using mutation breeding techniques to improve the productivity and quality of quinoa. "By using nuclear techniques the impact from negative traits can be reduced," said Ljupcho Jankuloski a geneticist at the Joint FAO/IAEA Division. Scientists have now developed varieties that are shorter, so easier to harvest, have a shorter growth cycle, and contain a lower amount of saponin, a naturally occurring detergent that gives the grain a bitter taste. The new varieties set to be released later this year will contribute to increased quinoa production and improved livelihoods of farmers, he said.

New mutant quinoa plants in Peru.

(Photo: L. Gomez-Pando/National Agrarian University of La Molina, Peru)

In recognition of the ancestral practices of the Andean people, who have through the centuries preserved quinoa in its natural state, as food for today and for generations to come, the United Nations General Assembly declared 2013 as the "International Year of Quinoa".

THE SCIENCE

Plant mutation breeding

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

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

You can't change what you can't measure: understanding greenhouse gas emissions in Costa Rica

By Michael Amdi Madsen

"The country needs more reliable data about its own emissions, and it needs to be able to gather those data itself."

— Ana Gabriela Pérez, researcher, University of Costa Rica

In Costa Rica climate change is a real concern. Sea level rise, climatic variability, and climate-induced disease outbreaks are likely to affect the availability of drinking water and threaten local amphibians and marine life. The country is committed to reducing its greenhouse gas emissions, and is now taking steps to learn how much greenhouse gases the dairy and agricultural sectors emit in order to determine what actions it can take to reduce the impact of climate change.

"A lack of training, equipment and national laboratory mean that Cost Rica relies on international emission factors to estimate the emissions of greenhouse gases from agriculture," said Ana Gabriela Pérez, a researcher at the University of Costa Rica, who is working to develop a national reference laboratory for the measurement of greenhouse gases in the country.

"Costa Rica aims to become carbon neutral by 2021, but the international greenhouse gas emission factors aren't very accurate for us. The country needs more reliable data about its own emissions, and it needs to be able to gather those data itself," Pérez said. One way of obtaining greenhouse gas data from different land uses is to team up with the IAEA to develop Costa Rica's analytical and instrumental capabilities in regard to nuclear techniques.

Atomic answers

Nuclear techniques offer substantial advantages over conventional techniques for measuring climate change impact (see box). "Stable isotope analysers let us monitor agricultural processes as they happen. They allow us to quantify carbon capture and emission patterns of farming practices, enabling us to find ways to improve them," Pérez explained.

Key to counterbalancing the increase of CO_2 in agriculture is carbon sequestration. Carbon sequestration is a process of changing agricultural practices to minimize emissions and to help remove CO_2 from the atmosphere by replenishing the depleting CO_2 stores in degraded soil — boosting soil productivity and resilience to harsh climate conditions.

Quantifying CO_2 emissions from soil provides a unique insight into changes in carbon decomposition rates and the balance of microbial respiration — which in turn can be used to drive changes in agricultural practices influencing soil processes and the release of CO_2. The accuracy and robustness of near-infrared laser beam technology allows the technique to create precise quantification of soil and carbon processes in croplands.

Nitrous oxide (N_2O) is a greenhouse gas that has 298 times more global-warming potential per unit mass than CO_2, and is naturally produced in soils during the microbial

How do greenhouse gases cause global warming?

Greenhouse gases are gases that trap heat in the Earth's atmosphere. They absorb and emit infrared radiation, causing what is known as the greenhouse effect — a process in which thermal radiation from the Earth is absorbed and re-radiated back to the surface, increasing the Earth's temperature by about 33 degrees Celsius in comparison with a situation in which there were no such gases at all. While this process is necessary for the maintenance of a temperate climate on the planet, the growing accumulation of greenhouse gases is now leading to global warming.

The primary greenhouse gases found in our atmosphere are water vapour, CO_2, methane, N_2O and ozone.

Analysis of field samples with Gas chromatograph with headspace autosampler.

(Photo: Ana Gabriela Pérez, researcher, University of Costa Rica)

processes of nitrification, co-denitrification and denitrification. "We can use nuclear techniques to determine whether N_2O is produced from the nitrogen in fertilizers or from nitrogen in the soil," Pérez explained. It is known from ^{15}N measurements that of total N_2O emissions, 10 to 40 per cent can be attributed to fertilizers and 60 to 90 per cent originate from the soil, Pérez added.

Real change for climate change

These new data, specific to Costa Rica, will help to design policy change in the country. Greenhouse gas emissions, and in particular the effects of fertilizers, form the basis of cost–benefit calculations that can be used to determine the right amount and kind of fertilizer to be applied in order to move towards carbon neutrality in the dairy sector.

The project is helping to bring about change with the involvement of the private sector through lectures and field studies at the University of Costa Rica and through the joint Livestock Commission of the Programme of Research and Transference of Technology.

The project in Costa Rica is one of many ongoing coordinated research projects run by the IAEA in cooperation with the Food and Agriculture Organization of the United Nations (FAO) that focus on reaching a more accurate and complete understanding of greenhouse gas emissions around the world, said Mohammad Zaman, a soil scientist at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Besides Costa Rica, the project also helps scientists from Brazil, Chile, China, Estonia, Ethiopia, Germany, Iran, Pakistan and Spain to enhance their ability to measure greenhouse gas emissions with greater precision as well as identify their exact source of production in soils, in order to apply mitigation measures, Zaman said.

THE SCIENCE

Using isotopes to study greenhouse gas production

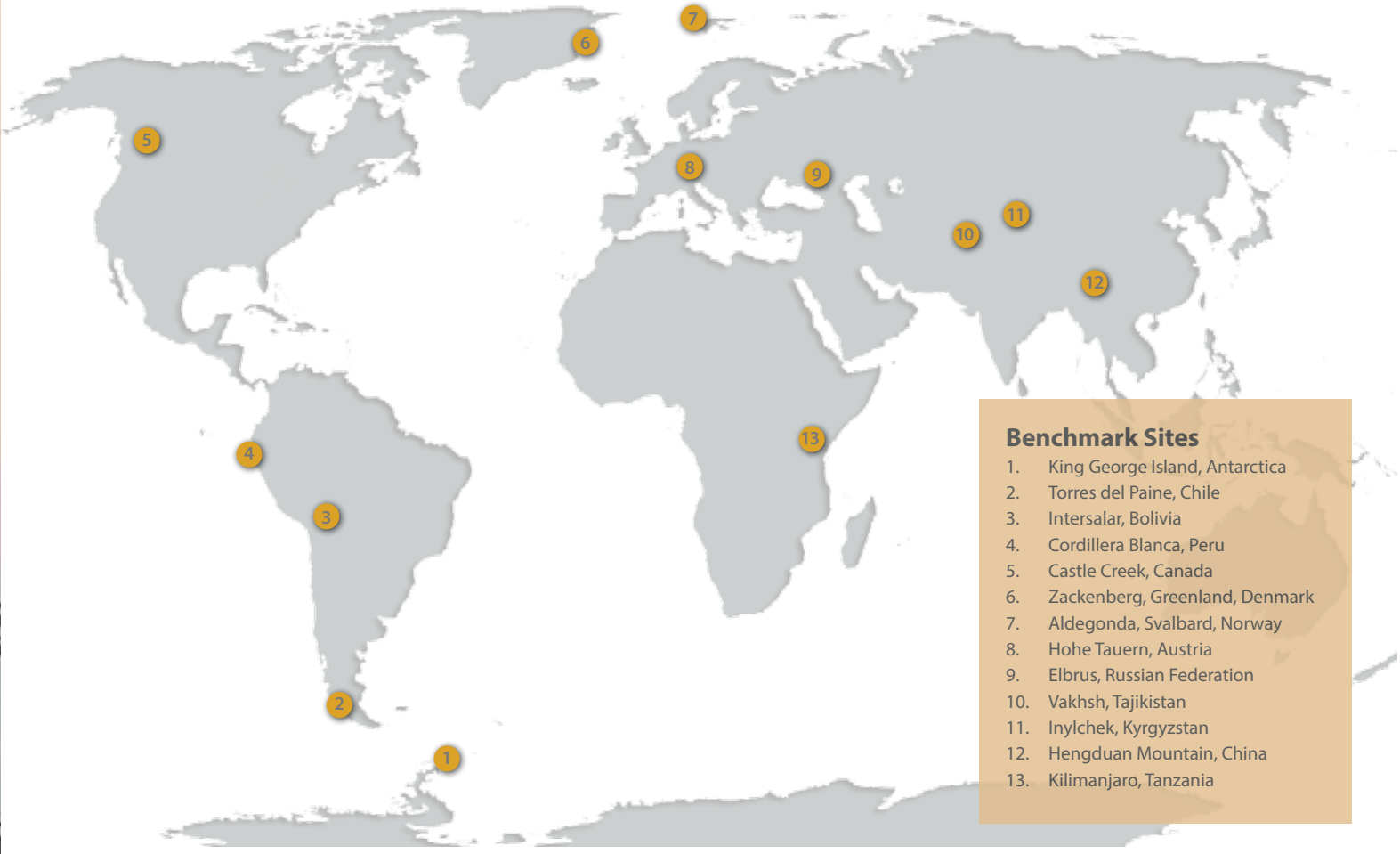
Isotopes are chemical elements (like carbon or nitrogen) that have the same number of protons but a different number of neutrons. Though isotopes chemically react in the same way, their differing atomic weights make it possible to distinguish between them. By using isotopes as tracers, scientists can track how elements move through complex cycles and see how they're involved in the production of specific molecules like those in greenhouse gases.

In the case of N_2O, scientists can analyse isotopomers (molecules with the same number of isotopes of each element but in chemically different positions) in nitrification, denitrification and co-denitrification processes within soil to study how nitrogen-based molecules change in these processes and what individual factors influence the production of this potent greenhouse gas.

A changing world

Using nuclear techniques to investigate the impact of climate change on polar and mountainous regions

By Sasha Henriques



Nuclear techniques are being used in polar and mountainous regions to study climate change and its impact on the quality of land, water and ecosystems in order to better conserve and manage these resources.

Researchers from around the world will be using data from 13 benchmark sites to draw conclusions about the effects of the rapidly changing climate on the Arctic, mountains and the western part of Antarctica, which have alarmed communities, environmentalists, scientists and policy makers. Between July 2015 and July 2016 they will be using isotopic and nuclear techniques, as well as geochemical and biological analytical methods from other scientific disciplines. This will enable them to track soil and water, to monitor the movement of soil and sediment and to assess the effects of melting permafrost on the atmosphere, as well as on the land, water and fragile ecosystems of mountainous and polar regions. The measurements follow numerous on-site tests carried out since November 2014 to perfect the sampling technique.

Many fear that climate change will cause soils to become unstable, and that there will be less water available for communities living in mountainous areas. There is also concern that greenhouse gases locked away in the soils of these regions for millennia will now find their way into the atmosphere, causing further changes to the Earth's climate.

The IAEA has embarked upon a four-year (2014–2017) technical cooperation project involving 23 countries and six international organizations to assess whether or not these climate change concerns are justified, and to identify what can be done if they are.

Although the project will be undertaken in polar and mountainous regions the results, especially those relating to permafrost and carbon in the atmosphere, can have global implications.

Gerd Dercon, Head of the Soil and Water Management and Crop Nutrition Laboratory of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, noted that the impact of climate change in mountainous and polar regions is "not always well understood. And that's why this project is so important. But also, this project is very significant in the context of looking at what happens when the cryosphere — that's snow cover, ice sheets, glaciers and

"I think that the success of this project will trigger collaboration between countries from all continents and between scientific disciplines, helping us to better study and understand climate change in mountains and polar regions."

— Bulat Mavlyudov, a glaciologist at the Russian Academy of Sciences' Institute of Geography

permafrost — changes, and what happens in terms of greenhouse gas emissions, soil water availability, sediment and sedimentary distribution, slope stability, and coastal erosion."

Peering into the past with isotopes

According to Heitor Evangelista da Silva, a paleo-climatologist from the Universidade do Estado do Rio de Janeiro in Brazil, one of the project's key components is the use of nuclear techniques to understand past climate behaviour in order to predict the future.

Isotope and nuclear techniques allow scientists to read the history of the Earth preserved in nature's own archives. These archives are the ice in glaciers or polar ice caps. They are the soil and sediments in lakes and oceans and organic matter in the earth or in trees. Isotopes are different forms of a single element, which vary in the number of neutrons that they have.

By measuring isotope composition and ratios in layers of sediment and ice it is possible to reconstruct climate history and variations in greenhouse gas concentrations over extremely long time periods. The same techniques can be applied to soil to extract information about how climate change in polar and mountainous regions affects the movement and quality of soil, and the production of greenhouse gases.

Gaining insight into past climate change events and how the environment responded to those changes is an excellent way of understanding current and future changes in climate and developing appropriate responses.

Adaptation — the bigger question

In July 2015, IAEA will conduct a training course in Svalbard, Norway, for around 20 fellows from different benchmark sites, teaching them how to use the required testing

Researchers on their way to collect soil samples on King George Island, Antarctica.

Scientists travel through an ice cave to get to the best sampling locations.

methods. Later, experts will also be sent to the various locations to provide follow-up instruction as needed.

This approach will ensure cross-comparability of the sampling and results analysis, an important element in this multi-country project.

Sample collection and analysis of the data will take place from July 2015 to July 2016. "If this phase of the project goes well, we will have another phase where we will then look at how we can adapt to climate change. Because assessing the impact is one thing, but the bigger question is how we can use this information to help communities in mountain regions adapt," said Dercon.

Collaboration and policy change

"I think that the success of this project will trigger collaboration between countries from all continents and between scientific disciplines, helping us to better study and understand climate change in mountains and polar regions," said Bulat Mavlyudov, coordinator of the interregional project, and a glaciologist from the Russian Academy of Sciences' Institute of Geography. "The results will be put to good use in formulating recommendations for climate change adaptation policy being looked at by the Intergovernmental Panel on Climate Change."

Members of the scientific research team that went to King George Island, Antarctica.

(Photos: G. Dercon/IAEA and B. Mavlyudov/ Russian Academy of Sciences)

A small river bringing large amounts of sediment down from the higher altitudes.

Analysing the age and quality of organic matter in soil can tell scientists a great deal about future climate change.

When surging seas meet stronger rain: nuclear techniques in flood management

By Rodolfo Quevenco

"Use of nuclear techniques will enable us to better track sources and pathways of diseases, nutrients, soil and water movement in the flood-affected areas."

— Raymond Sucgang, senior science research specialist, Philippine Nuclear Research Institute

Unusually high rainfall in many parts of the world is a result of climate change, scientists say. Since warmer air can hold more water, the rationale goes, increased temperatures will increase the chances of stronger rainfall events. And when surging seas combine with stronger rain, the outcome is almost certain: floods.

Floods are the most frequently occurring natural disasters, and south-east Asia is particularly vulnerable. Climate change and variability are expected to bring about increased typhoon activities, rising sea levels and off-season monsoon rains in south-east Asia and other regions. These can cause devastating floods in countries like Cambodia, Laos, Pakistan, the Philippines, Thailand and Viet Nam.

For the residents of these countries who have survived the ravages of major floods, the road to recovery can be long and arduous. As the flood water recedes, they have to contend with new forms of flood: floods of concern and worries as to how to rebuild their houses, their lives and their cities. Governments, too, face huge challenges in rebuilding roads, public buildings, infrastructure and natural resources destroyed or polluted by the flood.

Rebuilding with scientific tools

A flood-stricken area must be restored before any development can be carried out. To this effect, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture has launched large-scale multi-year projects in the region to help flood-affected countries to rebuild key resources and put in place measures that will lessen the impact of future floods.

These projects will use nuclear and isotopic techniques to identify an integrated solution to flood management, both before and after major flooding events (see box).

"Use of nuclear techniques will enable us to better track sources and pathways of diseases, nutrients, soil and water movement in the flood-affected areas," said Raymond Sucgang, a senior science research specialist at the Philippine Nuclear Research Institute.

"This knowledge will be highly valuable in helping the country establish an integrated solution for flood management and rehabilitation based on sound scientific knowledge," Sucgang added.

Experts from Australia and New Zealand will visit the areas most affected by Super Typhoon Haiyan, which devastated the eastern seaboard of the Philippines in November 2013. The experts, working under an IAEA-supported project, will survey the affected areas and propose nuclear techniques to use in identifying sediment sources, as well as training local counterparts in the use of isotopic and other techniques, Sucgang explained.

Local officials want to assess the changes in circulation, dynamics and quality of groundwater in Tacloban City caused by Typhoon Haiyan, to study the dynamics of the area's natural recovery process, and to try to accelerate the remediation of the affected environment.

There is a widespread belief that flooding brought about by the accompanying storm surge might have contaminated the city's groundwater and aquifer systems with decaying organic matter, cadavers and seawater. Surrounding fields may also no longer be fit for agriculture due to the presence of salt and flood-borne contaminants in the soil.

Local authorities, however, need access to reliable and effective scientific information on which to base their plans, policies, actions and mitigation strategies. Nuclear techniques are powerful tools that can unearth this much-needed information.

A Regional Approach to Flood Management

The work in the Philippines will serve as a pilot for assistance to other countries in the region.

The overall goal is to improve the capacity of Asian countries to use nuclear techniques in developing agricultural systems that are resilient and can adapt to flooding events, said Lee Kheng Heng, Head of the Soil and Water Management and Crop Nutrition Section at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Efficient use of nuclear and isotopic techniques will help them generate flood-tolerant crops, improve soil-water nutrient management practices for flood rehabilitation and adaptation, optimize the use of local feed resources and rapid diagnosis of animal diseases, perform comprehensive water resource assessments for forecasting potential floods, and develop strategies to exploit the potential of flood plains to absorb flood water, she explained.

Planned activities include a training course at the IAEA's laboratories on early detection of animal diseases in a post-flooding environment with an emphasis on waterborne and vector-borne diseases; a training course in China on the use of fallout radionuclide and compound specific stable isotopes and other relevant techniques in flood-risk mitigation and post-flood rehabilitation efforts in Asia; and a regional training course in Thailand on the use of isotope and geochemical applications in flood-risk mitigation. In addition, Argonne National Laboratory in the United States is funding a workshop for decision makers to raise awareness of the importance of flood management and mitigation.

"Together, these activities will help strengthen Member States' capacities in using nuclear techniques in combination with conventional approaches and strengthen national and regional collaboration in flood management. They will also ensure that scientific knowledge is available to them to forecast when the next flood may come, as well as its potential extent," Lee Heng said.

For residents of the Philippines who have weathered a major flood, the road to recovery can be long and ardous.
(Photo: International Rice Research Institute)

THE SCIENCE

Use of stable isotopes in flood control and rehabilitation

Using nuclear and isotopic techniques in combination with conventional approaches, scientists can efficiently study the effects of flooding on groundwater and aquifer systems, and determine the time needed for these resources to heal themselves and return to pre-flood status. Scientists rely heavily on isotopic techniques to develop or identify flood-tolerant crops; study soil erosion trends and pathways of pollution from flood waters; and improve soil, water and crop management practices to minimize flood peaks and adapt to flooding events.

These techniques mostly employ stable isotopes, which are not radioactive or, in the case of tritium, have very low radioactive concentrations.

At the same time, applying isotope technology to area-wide soil and water storage monitoring of irrigation systems helps to enhance a country's ability to forecast future floods and the potential damage they may cause.

Ocean acidification: the little-known impact of CO_2 emissions

By Michael Amdi Madsen

(Photo: M. Madsen/IAEA)

"Recognizing that billions of people are dependent on a healthy ocean for their well-being and economic development is the first step."

— Alexandre Magnan, Institute for Sustainable Development and International Relations

Ocean acidification, like global warming, is a serious consequence of rising carbon dioxide (CO_2) emissions and a growing threat to coastal communities. Scientists and economists alike are calling for ocean acidification mitigation and adaptation plans to be included in any future international climate change agreement, arguing that doing so would make any such agreement stronger and facilitate its implementation. The IAEA uses nuclear techniques to measure ocean acidification and has been providing objective information to scientists, economists, and policymakers to make informed decisions.

"Recognizing that billions of people are dependent on a healthy ocean for their well-being and economic development is the first step," said Alexandre Magnan of the Institute for Sustainable Development and International Relations in Paris at an IAEA workshop this year. Acknowledging in the legal text of a climate deal the threats facing the oceans could open the door for coastal communities affected by ocean acidification to benefit from financing available under a climate change agreement, he said. This would enable them to adapt to changing social and economic circumstances, improve understanding of the ecological and biophysical changes expected, and pressure further concrete actions by governments, he added.

There has been a 26 per cent[1] increase in ocean acidity since pre-industrial levels as a result of the release of CO_2 into the atmosphere, and the current rate of ocean acidification is over ten times faster than that of any other period in the last 55 million years[2], data show.

The annual Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC COP), held in Lima, Peru, in December 2014, made significant progress towards a new multilateral agreement, but the challenges facing the oceans and coastal communities dependent on marine ecosystem services remained essentially absent, experts have said.

[1]INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, "Social, economic and ethical concepts and methods" and "Drivers, trends and mitigation", Climate Change 2014: Mitigation of Climate Change, IPCC, Cambridge University Press, New York (2014) Ch. 3 and Ch. 5

[2]HÖNISCH, B., et al., The geological record of ocean acidification, Science 335 (2012) 1058, 1063.

A system in decline

Some effects of ocean acidification and global warming are already apparent, said Ove Hoegh-Guldberg of Queensland University's Global Change Institute. Australia's Great Barrier Reef, which provides a protective barrier during storms, is a tourist attraction, and acts as a nursery for fish, has declined in size by as much as 50 per cent in the last 30 years, Hoegh-Guldberg explained, adding that it is not yet clear how much reef can be lost without wider consequences.

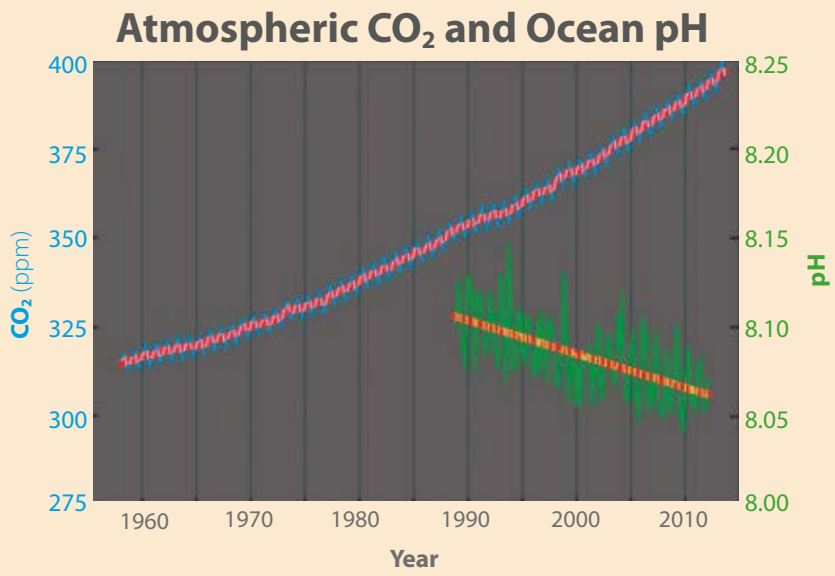
Hoegh-Guldberg and his colleagues are developing models to show how ocean acidification and reef loss will have an impact on the wider ecosystem and people, in order to guide policymakers towards a decision.

For many, the next frontier in ocean acidification research is to study its effects on ecosystems. Examining individual species in isolation does not provide enough information to establish the amount of CO_2 oceans can absorb without major harm to their flora and fauna, said Sam Dupont, a researcher at the University of Gothenburg's Department of Biological and Environmental Sciences. "We need to look at entire mechanisms, not just species."

The role of nuclear science

Nuclear science has a role to play in understanding the effects that climate change and ocean acidification have on the oceans. The IAEA's Ocean Acidification International Coordination Centre, based in Monaco, uses nuclear techniques to understand processes and changes in the marine environment. The use of radioisotopes, such as calcium-45 and carbon-14, provides important information on the rate and impact of ocean acidification. The Centre implements international activities and facilitates global communication in order to make the most effective use of science.

"Nuclear techniques are used by many research centres around the world to provide very specific data, underpinning the scientific community's growing understanding of the severity and impacts of ocean acidification," said David Osborn, Director of the IAEA's Environment Laboratories. "This is key to anticipating economic and social impacts."

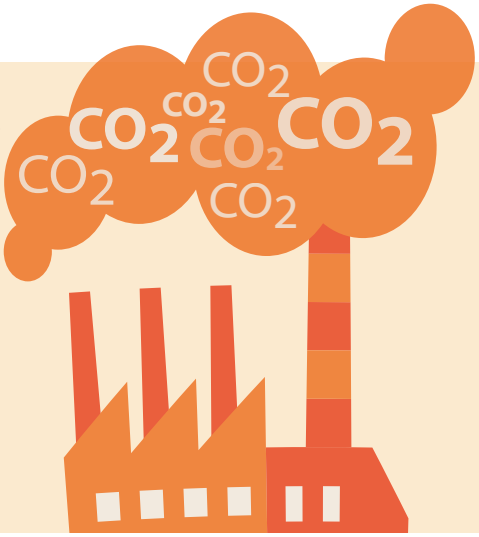


Observations of CO_2 (parts per million) in the atmosphere and pH of surface seawater from Mauna Loa and Hawaii Ocean Time-series (HOT) Station, Aloha, Hawaii, North Pacific.

Source: Adapted from Richard Freely (NOAA), Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends) and Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu)

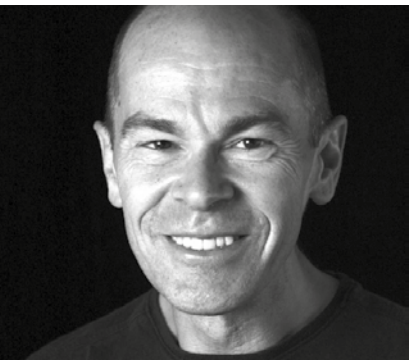
What is ocean acidification?

Some of the CO_2 released into the atmosphere gets absorbed by the oceans. The CO_2 reacts with water molecules (H_2O) to form carbonic acid. Carbonic acid is a weak acid, but even slight changes in ocean acidity can have dramatic impacts on some organisms and cause knock-on effects throughout the food chain. These knock-on effects can affect humans too, with impacts on the livelihoods and food security of billions of people.



The nuclear option
The case for using nuclear power to combat climate change

By Robert Stone



Robert Stone is an Oscar-nominated, internationally acclaimed documentary film-maker. His most recent film, Pandora's Promise, chronicles the transition of several leading environmentalists from anti-nuclear to pro-nuclear in the face of climate change, and the promise of next-generation reactor technology. He recently co-founded the non-profit organization Energy for Humanity, a pro-nuclear environmental advocacy group based in London.

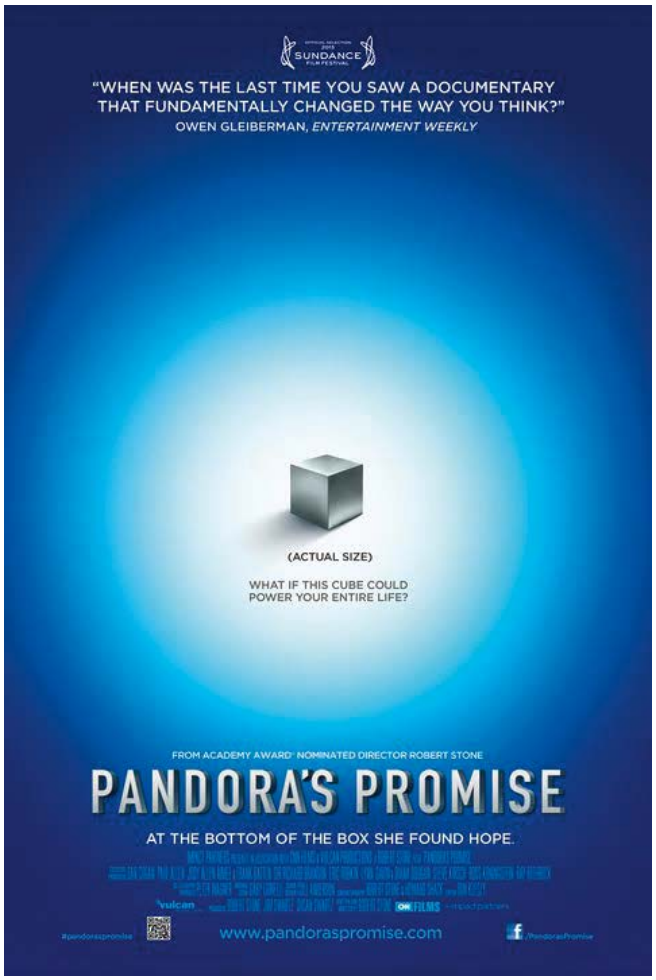
In December 2015, world leaders will gather in Paris to hammer out a global treaty designed to ratchet back emissions of CO_2 into the atmosphere caused by the burning of fossil fuels. I would urge each delegate, upon checking into his or her hotel room, to step out on to the balcony, take a deep breath, look out at the lights of nuclear-powered Paris and draw inspiration for what a clean energy future might look like. Thanks to France's decision to deploy nuclear power in a big way some 30 years ago, the country's electric grid is now almost entirely carbon free. What's even more remarkable is that the vast majority of that transition was carried out in just 11 years (1969–1980), using the technology of the time. France today enjoys almost zero air pollution from the production of electricity and the cheapest electricity rates in western Europe.

Will the climate activists and delegates take heed of what France has accomplished and look to it as a precursor of what might be possible globally? Preliminary negotiations in Lima in late 2014 have taken nuclear energy off the agenda of the climate talks. The world's leading environmental groups, which are largely driving the agenda, posit that nuclear energy is an unnecessary distraction on the road to a renewable energy future. In making their case they argue that humanity can reduce overall energy demand while simultaneously providing adequate energy to the 3 billion people who currently live with little or no electricity at all, and take care of the additional 3 billion people to be born between now and 2050. They argue that we are on track to being able to replace the entire existing fossil fuel infrastructure, abandon nuclear energy altogether, and meet all the world's energy needs by using renewable energy alone. And we've barely begun to talk about the additional energy that will be required to electrify the world's transportation sector and meet the growing demand for energy-intensive water desalination.

It's a wonderfully compelling vision that it is within our grasp to inhabit a world in which all of humanity could be supplied with unlimited clean energy from the wind and the sun. A great many environmental activists have devoted their lives to realizing this dream. The trouble is that there's little evidence to suggest that any of this is practically possible in the real world. There have been a few widely cited academic studies that demonstrate how with unlimited political will and unlimited resources, coupled with an assumed steep decline in global energy demand, there's at least a theoretical basis for imagining it could be carried out. Germany, which is abandoning nuclear energy, is widely believed among environmentalists to be an example of a nation well on its way towards being almost entirely powered by renewable energy. In fact, Germany gets 5% of its electricity from solar power and about 8% from wind (more than any other major industrial nation). This still leaves 87% of the country's electricity needs coming from other sources — including hydro and biomass, but mostly fossil fuels. Germany is also one of the only European nations that continues to build new coal plants.

There is no assurance that we'll be able to reverse the current trends that are hurtling us towards a potential climate catastrophe. But I believe we are irresponsibly diminishing, and very likely eliminating, our chances of success if we insist on trying to solve this problem without deploying nuclear energy in a big way. In a world that is adding the energy equivalent of another Brazil to the planet every year, and where coal remains not only the most widely used source of energy, but also the

fastest growing, nuclear energy has the potential to make a significant contribution to the type of clean energy mix that will be required if we are to seriously scale back on our dependence on fossil fuels globally. Nuclear is by no means the only solution to every locality or situation. Wind, solar, hydro, increased use of natural gas in the short term, and perhaps advances in carbon capture and storage technology, are all components of an overall transition to clean energy. But removing the unique potential of nuclear energy from the equation, as the climate activists set to gather in Paris seem determined to do, is to risk disaster.



Critics of nuclear energy point out that the current iteration of the large-scale light water reactor is constrained politically and economically as a sustainable and viable solution to our global energy challenges. What is often ignored, however, is the fact that many cutting-edge advanced reactor designs, the science for which has been developed over many decades, are nearly ready to be commercialized (and would be now had anti-nuclear groups not rallied to cut off research and development funding years ago). The next generation of nuclear plants have the ability to play a transformative role in providing clean energy on the massive scale that will be required to meet the new climate targets. Using today's nuclear waste for fuel, plus the ability to extract uranium from seawater or switching to an abundant thorium fuel cycle, assures a virtually inexhaustible supply of fissionable material to meet the electricity needs of everyone on the planet essentially forever, while virtually eliminating the accumulation of long-lived radioactive waste. Passively safe advanced designs, like molten salt reactors and small modular reactors, offer the promise of dramatically improved economics for nuclear energy by minimizing the need for the kinds of costly and complex safety systems required for today's nuclear power plants. Mass production of modular components on assembly lines, rather than on-site construction, can streamline the production process and allow for a rapid scaling of the technology at dramatically lower cost. The same manufacturing techniques used today to produce commercial jet aircraft — an even more complex, yet remarkably safe and reliable technology — could soon be turning out standardized, modular nuclear power plants at a rapid clip. It can be done.

To the delegates soon to gather in Paris, look out of your window when you get there, and take in the view. The proof-of-concept of a fully implemented, nation-scale transition from fossil fuels to clean energy is staring you in the face.

Does nuclear power really help us fight climate change?

By Mikhail Chudakov

"Nuclear power is the only low-carbon technology that is available today that has the potential to be deployed on a wide scale and in large capacities to help meet the global climate–energy challenge."

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

Having been a nuclear power reactor operator for a good part of my career, I understand very well the potential of nuclear energy. I have seen many improvements in technology and operational safety, as well as the financial and environmental benefits they have brought.

The global community is facing a double challenge: the world's population, level of development and, consequently, energy demands are steadily rising; at the same time, we must understand, mitigate, and adapt to climate change, which is an unfortunate by-product of increased energy use.

Nuclear power is the only low-carbon technology that is available today that has the potential to be deployed on a wide scale and in large capacities to help meet the global climate–energy challenge. First, direct greenhouse gas emissions from nuclear power plants are negligible. Secondly, when emissions over the entire life cycle are considered, hydro, nuclear, and wind-based electricity generation are the lowest CO_2 emitters. Therefore, nuclear energy is ideally placed to mitigate the effects of climate change in a most cost effective way.

An increasing number of IAEA Member States concerned about climate change are now considering introducing nuclear power into their national energy mix or expanding its use. The IAEA has a comprehensive set of tools to help them understand the climate–energy challenge as well as the challenge of launching a nuclear power programme. Our efforts focus on providing a factual assessment of nuclear power. We help decisionmakers consider all energy production technology options. Our planning tools, used by 130 countries and 20 regional and international organizations, consider all energy options. But if and when a Member State so requests, we provide assistance for the safe, secure and sustainable implementation of their nuclear power programme.

Our support covers many areas: from energy planning to responsible uranium mining, from reviewing national infrastructures to training, from operational performance to tackling radioactive waste, decommissioning and environmental remediation.

Nuclear power produces about 11% of global electricity. Our projections show nuclear energy continuing to play a key role in the global energy mix for decades to come. The Fukushima Daiichi nuclear accident has slowed the growth of nuclear power, but has not reversed it. This continued growth suggests that the fundamentals supporting continued use of nuclear power have not changed. The safer the reactors are and the better they perform, the less CO_2 will be released. In 2011 alone, it is estimated that 2.1 gigatonnes of CO_2 emissions were avoided due to nuclear-based electricity generation.

I believe that advanced and innovative reactor and fuel designs will play an increasing role in meeting this global challenge. Use of gas-cooled and fast reactors, for example, will improve fuel utilization, help optimize fuel cycles, reduce cooling water demands, and minimize long lived radioactive waste generation.

The Department of Nuclear Energy takes the lead in the IAEA's efforts to bring about innovation in nuclear power. We try to connect the many disciplines that are involved in advanced reactors, ranging from financing to better use of resources, from operational performance to waste management and proliferation resistance. Nuclear power has been a reliable source of the world's electricity supply for over half a century. So my answer to the critical question "Does nuclear power really help us fight climate change?" is a clear YES. We will continue to help Member States in their efforts to use nuclear power in a safe and sustainable way.

Open for applications: IAEA Coordinated Research Activities in 2015

Research institutes and organizations interested in gaining access to vast global databases of research findings and taking part in papers submitted to high-level, peer-reviewed journals can now submit a proposal for a research contract or agreement to take part in IAEA-coordinated research activities this year.

More than 1600 research institutions are already working collaboratively through over 100 active IAEA-coordinated research activities on a broad range of topics, including, among others, improving diagnostics and treatment of cancer and cardiovascular diseases, better understanding climate change and coastal pollution using isotopic tools, developing reactor safety designs, and increasing agricultural efficiency.

The purpose of these projects is to encourage both the acquisition and dissemination of new knowledge and technology generated through the use of nuclear technologies and isotopic techniques, as well as the adaptation of technologies in IAEA Member States. Results of these projects are disseminated to Member States and the international scientific community through publications. Findings from IAEA-coordinated research projects often result in significant practical applications.

The IAEA is announcing around 50 new project proposals this year and invites all interested institutions to submit research proposals on the topics outlined here: cra.iaea.org/cra/info-letter.html.

"These coordinated research projects allow research institutes, regardless of their size or location, to expand their reach," said IAEA Deputy Director General Aldo Malavasi. "It is a great opportunity to share and add to a profound knowledge database and coordinate with others on some of the most important scientific studies under way today on the wide, peaceful and beneficial applications of nuclear technology."

Funding is available to cover the cost of minor equipment and to act as seed money, with the bulk of the expenses covered by Member States. The average grant is approximately 6500 euros per year.

The IAEA is inviting all those interested to submit a proposal to join in the exploration of frontiers in nuclear technology and isotopic techniques. The application process can be accessed here: cra.iaea.org/cra/forms.html.

— By John Brittain & Nicole Jawerth

Over 1600 research institutions are working collaboratively through over 100 research activities coordinated by the IAEA.

(Photos: IAEA)

Mongolia and IAEA: successful cooperation, renewed focus on cancer care

Replacements for existing radiotherapy treatment units and the forthcoming installation of two new linear accelerators will greatly boost Mongolia's national cancer programme and reduce waiting times for patients, the country's officials have said. The last few years have seen an increase in cancer cases in Mongolia, and "being a developing country, we need all the support that the IAEA can provide us," said Minjmaa Minjgee, a radiation oncologist with the National Cancer Centre in the capital Ulan Bator.

Effective treatment through quick diagnosis

IAEA support has been crucial for Mongolia in the acquisition of a gamma beam radiation protection system and an X-ray calibration system to support the country's cancer control, diagnosis and treatment programme. The IAEA is also assisting Mongolia in upgrading a computed tomography and single photon emission computed tomography medical imaging system at the First General Hospital in Ulan Bator. In addition, there are plans to install two linear accelerators in a new hospital extension building that will be inaugurated later this year. The possibility of installing advanced 3D brachytherapy facilities for patients in 2016 is also under consideration.

The presence of such state-of-the-art technology in Ulan Bator will enable Mongolia to treat more cancer patients, and will help to reduce the long waiting times.

"Time is of the essence where cancer is concerned; quick diagnosis and effective treatment in a timely manner can help patients, and these radiotherapy machines are what we need to meet this goal of ours," Minjgee said. In addition, the IAEA's resource mobilization assistance to Mongolia resulted in significant funding provided by Japan and Monaco for upgrading the radiotherapy treatment planning system's hardware and software at the National Cancer Centre.

Progress achieved

Mongolia is one of the most sparsely populated countries in the world, making the provision of universal cancer care particularly challenging. A population of just under 3 million is spread over an area of more than 1.5 million square kilometres — larger than France, Germany and the United Kingdom combined.

"Our objective is to provide access to cancer diagnosis and treatment to people from the countryside so lives can be saved," Minjgee said. "We highly value international cooperation and support, including with the IAEA, to help us improve the quality of medical care and services in cancer treatment, which today is an urgent health problem." Cancer is responsible for 22 per cent of deaths in the country, second only to cardiovascular diseases.

Since 1995, the IAEA has been helping Mongolia to enhance its national cancer programme, by providing policy advice, equipment and technical training. Three major technical cooperation projects have been successfully implemented: improving radiotherapy services; upgrading quality assurance; and developing new technologies and radiation safety systems for radiotherapy services.

Mongolia has also received assistance through the IAEA Programme of Action for Cancer Therapy related to paediatric cancer care, palliative care and training in radiation medicine. Following policy assistance in 2010 the country's General Action Plan on Cancer Prevention and Control for 2011–2021 was developed and endorsed.

Planning for the future

Since it joined the IAEA in 1973, Mongolia has received assistance in using nuclear applications to improve the lives of its people in various sectors, including diagnosis and treatment of animal diseases. The livestock sector is one of the most important for the majority of the population in Mongolia, and the IAEA helps to improve the productivity of cattle, camels and yaks through better nutrition and reproductive management.

Minjmaa Minjgee, radiation oncologist, National Cancer Center, Ulan Bator, Mongolia.

(Photo: S. Henriques/IAEA)

"The concrete steps taken through IAEA projects to support Mongolia in a number of areas using the peaceful applications of nuclear techniques has helped our country and our people," said Tamir Nyambayar, the country's former National Liaison Assistant to the IAEA.

Last March Mongolia finalized its Country Programme Framework for 2016–2021, integrating the application of nuclear technology into its development plans. The Framework defines priority development needs and interests that can be supported through the IAEA's technical cooperation activities. The emphasis for the coming period is on human health, Nyambayar said.

— By Aabha Dixit

Action at sea: transport security exercise conducted off the coast of Sweden

As in an action movie, ships, helicopters and uniformed people set the scene off the coast of Sweden on 6 May 2015 when national authorities conducted an exercise on security while transporting spent nuclear fuel.

The exercise was part of a joint project with the IAEA to test and evaluate a new IAEA guide on planning, conducting and evaluating transport security exercises. The test subject and model was the security framework of Sweden's national nuclear transport system, which regularly ships used fuel from power plants along the coast to the country's interim storage facility for spent nuclear fuel.

"In addition to supporting the IAEA in the development of the exercise guide, the field exercise provided an excellent opportunity for training in a realistic situation not only for the regulatory authority, the coastguard and the police counterterrorist unit, but also for the company responsible for transport operations," said Tommy Nielsen, the Exercise Director from the Swedish Radiation Safety Authority. "This exercise was also a chance for Sweden to further improve its national transport security system."

The IAEA reviewed Sweden's nuclear transport security system in 2011 and provided advice on implementing international standards and IAEA guidance on the physical protection of nuclear and other radioactive material and associated facilities, including good practices, recommendations for improvement and follow-up activities. Sweden subsequently became closely involved with the IAEA in the development of the exercise guide.

A helicopter helped to regain control of the vessel during the field exercise. (Photo: Swedish Police)

A scenario at sea

The field exercise was a full-scale, comprehensive scenario involving national authorities overseeing the M/S Sigrid, a purpose-built vessel carrying a shipment of fake spent nuclear fuel from the Forsmark nuclear power plant. The scenario unfolded as the vessel headed south to an interim storage facility and was intercepted by an unidentified armed group, which took control of the vessel and forced the crew to comply with their instructions.

The authorities jumped into action. Relying on their prepared plans and extensive training, personnel from the Swedish Radiation Safety Authority, the national police force, the coastguard and the Swedish Nuclear Fuel and Waste Management Company worked together to regain control of the vessel. Their plans were carefully designed on the basis of national regulations and training, as well as IAEA nuclear transport security guidelines and preparatory exercises. The transport security strategy also relied on results from a tabletop, discussion-based exercise involving around 100 participants and observers held in February 2015 as part of the exercise preparations.

With close coordination and quick thinking, the authorities successfully overcame the attacking group and recovered control of the vessel.

"To be able to exercise under realistic conditions is of critical importance for my personnel," said Göran Kessell, Superintendent of the Swedish police. "The cooperation with the coastguard and the support from other stakeholders was key for us to plan our operation and to successfully regain control of the vessel on the open sea."

Throughout the day, real-time progress updates from the field were sent to observers from the IAEA and 15 countries who gathered in a nearby facility onshore to follow and discuss the exercise. The more than 40 international participants had a chance to learn about these types of exercises, to see the resources involved, and to hear first-hand accounts of the exercise and its preparation.

"Events such as this exercise help raise security standards across States and

contribute towards a consistent, safe and secure approach to the transport of nuclear material. We welcome the chance to learn and share good practices in an international forum. The United Kingdom is grateful to Sweden and the IAEA for the opportunity to observe the exercise," said Steve Skelton, Principal Inspector of the United Kingdom Office for Nuclear Regulation.

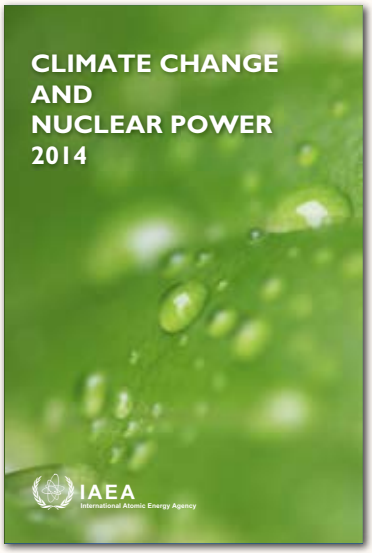
A timely and handy exercise guide

Results from the pilot exercise, which was held from 5 to 7 May 2015, will be used to improve the IAEA guide, complementing the results of the tabletop exercise and the input from experts from several Member States and other partner organizations. The guide will provide comprehensive information to help States to properly test, validate and implement their national nuclear transport security plans and arrangements, including interagency coordination, in line with international instruments and IAEA guidance.

"The transport security exercise guide will be an important tool for the IAEA to assist States, upon request, in the practical implementation of IAEA transport security recommendations and guidance," said Khammar Mrabit, Director of the IAEA's Division of Nuclear Security. "Tabletop exercises and field exercises should be utilized to test and validate transport security plans. No plan is better than the one that is exercised and tested. The Agency is ready to continue assisting States in this regard."

— By Stig Isaksson and Nicole Jawerth

Publications alert



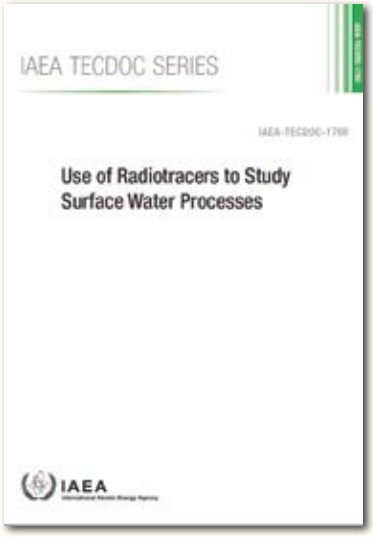
The 2014 Climate Change and Nuclear Power

report provides a comprehensive examination and analysis of the role of nuclear power in mitigating global climate change and how it contributes to meeting other developmental and environmental challenges. It discusses the environmental benefits of using nuclear energy to help reduce local and regional air pollution, and considers climate change adaptation measures, such as seawater desalination or hedging against hydropower fluctuations.

The report also examines broader issues, such as cost, safety, waste management and recent technology developments. In addition it presents the 2014 nuclear power projections of the IAEA and explores emerging issues that will affect the relationship between climate change and nuclear power in the coming decades.

The 2015 edition will be published in the last quarter of this year.

www-pub.iaea.org/books/IAEABooks/10771/Climate-Change-and-Nuclear-Power-2014

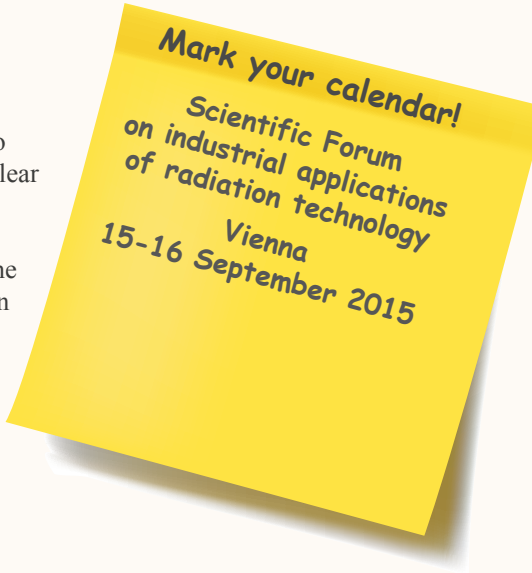


Use of Radiotracers to Study Surface Water Processes

is a key reference for all those concerned directly or indirectly with surface water processes. It provides a knowledge base for conducting radiotracer studies in marine environments . Radioactive tracers, or radiotracers, are chemical compounds in which one or more atoms have been replaced by a radioisotope. They can be extremely useful in studying natural and anthropogenic processes, such as climate change, that modify water flux and quality and have a direct impact on human lives. The publication describes in detail radiotracer technology, as well as methodologies, study design, measurement and analysis related to radiotracers . The publication also provides guidance on training in the use of radiotracers and includes environmental case histories from five Member States — Australia, Brazil, France, the Republic of Korea and Sweden — which provide information on conducting studies involving the use of radioactive tracers.

www-pub.iaea.org/books/IAEABooks/10689/Use-of-Radiotracers-to-Study-Surface-Water-Processes

ATOMS IN INDUSTRY
Rays of hope for development



What are the uses of radiation technology, and what benefits does it bring to our lives? The public has little awareness of how widespread the use of nuclear techniques is beyond the generation of power and cancer therapy.

This year's Scientific Forum, to be held on 15 and 16 September 2015 on the margins of the 59th IAEA General Conference, will showcase how radiation technologies are used in a broad range of industries.

Entitled 'Atoms in Industry — Radiation Technology for Development' and bringing together experts, industry leaders and researchers, the Forum will examine best industry practices from around the globe and serve as a platform to exchange ideas on how these technologies can be applied to propel development efforts.

"Helping countries to benefit from the peaceful use of nuclear technology is a central area of the IAEA's work. Our assistance covers areas including human and animal health, food security, water management, electricity generation, and environmental protection — to name just a few," said IAEA Director General Yukiya Amano.

In 2014, over 130 countries received support through the IAEA's technical cooperation programme, and while nuclear technology is often equated with nuclear power in the eyes of the general public, 80% of IAEA Member States are in fact non-nuclear power countries.

From the cars, trains and aeroplanes that people board daily to the cables that power day-to-day activities and the instruments that measure the safety of our homes, nuclear techniques are used extensively to meet the needs of modern life.

Radiation is an effective tool to kill germs and harmful organisms in health care and food industries, and radiation techniques used, are environmentally friendly ways to measure and clear pollutants in rivers, as well as to test and change the properties of materials in order to improve their structure and resilience.

The Forum will also look at innovative uses of radiation technology, such as in the preservation of cultural heritage and in the processing of new, environmentally friendly materials, and at how these techniques can contribute to boosting productivity.

"We want to take a closer look at the role nuclear techniques can play in industry in developing countries, and in cooperation with Member States and other partners, identify how we can assist in priority areas where nuclear techniques can add value," Mr Amano said.

For more information visit www-pub.iaea.org/iaeameetings/46532/Scientific-Forum-Atoms-in-Industry-Radiation-Technology-for-Development

— By Luciana Viegas

International Atomic Energy Agency Scientific Forum

ATOMS IN INDUSTRY

Radiation Technology for Development

15–16 September 2015, Vienna, Austria
Boardroom D, C Building, 4th Floor

IAEA
International Atomic Energy Agency
Atoms for Peace

CN–230

ISSN 0020-6067

15-1529

15-10431