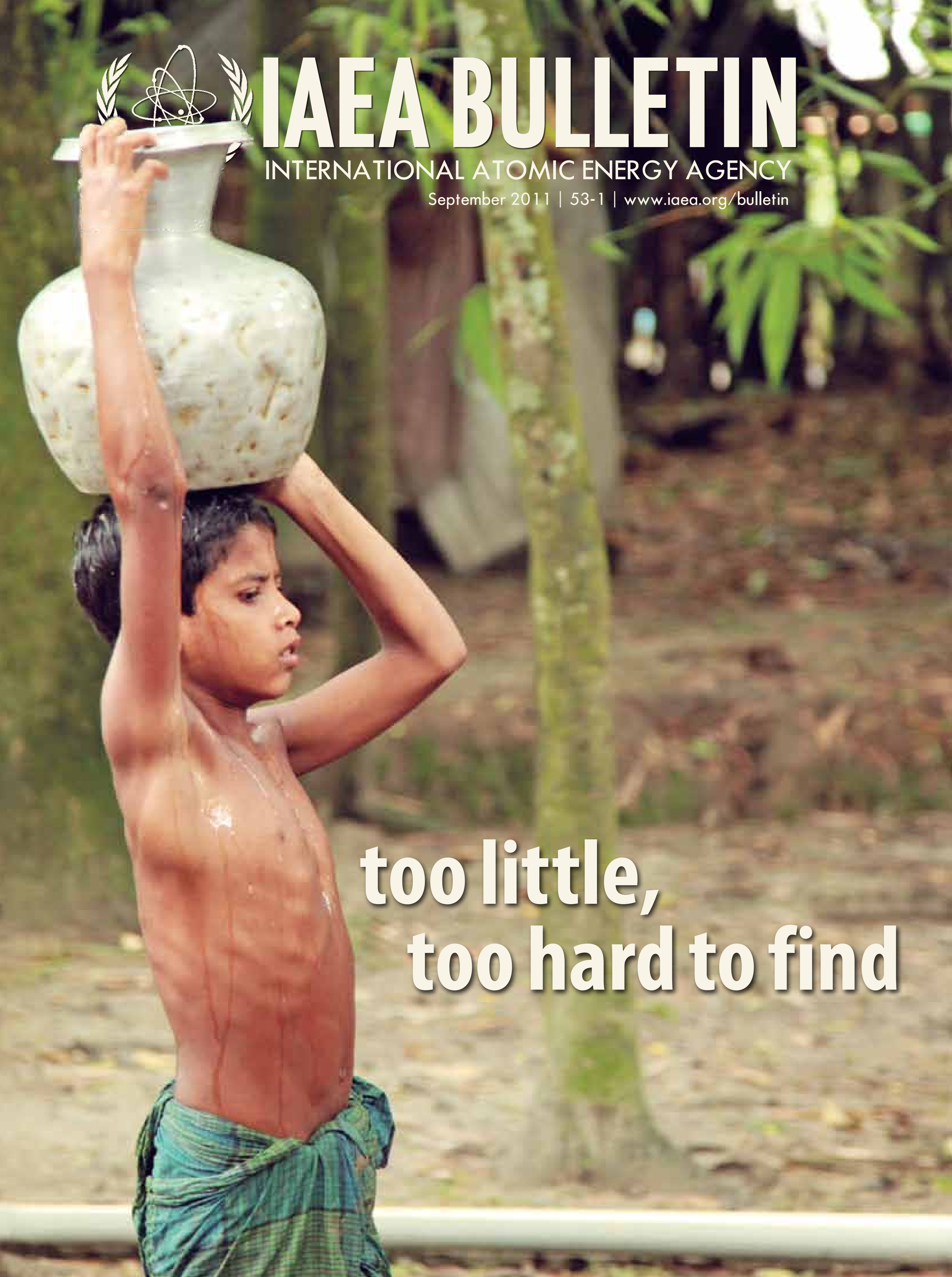

IAEA BULLETIN

INTERNATIONAL ATOMIC ENERGY AGENCY

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too little, too hard to find

Water for Santa Elena • Farming When the Rains Fail • Protecting Coastal Waters

IAEA

The International Atomic Energy Agency serves as the world's foremost intergovernmental forum for scientific and technical cooperation in the peaceful use of nuclear technology. Established as an autonomous organization under the United Nations in 1957, the IAEA carries out programmes to maximize the useful contribution of nuclear technology to society while verifying its peaceful use.

The IAEA helps its Member States pursue their developmental goals by supporting the responsible planning and use of nuclear science and technology. The IAEA facilitates the transfer of the knowledge and technology needed by developing Member States to utilize these technologies peacefully.

By developing nuclear safety standards, the IAEA promotes the achievement and maintenance of high levels of safety in nuclear energy applications, as well as protecting human health and the environment against ionizing radiation.

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

The 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, Trieste.

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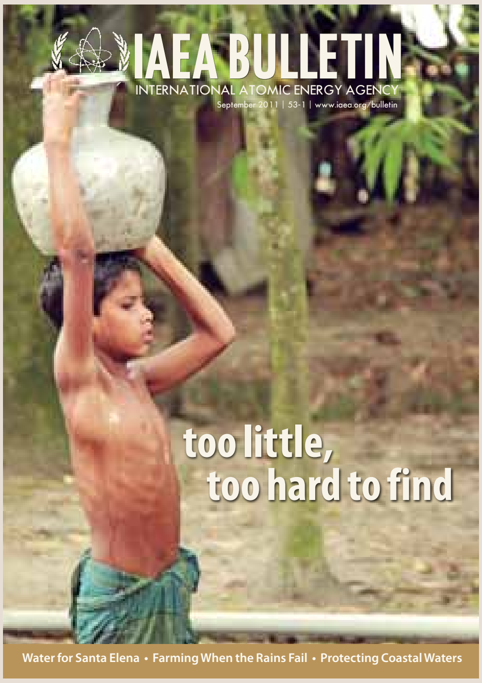

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Cover Photo: A young boy from Kishoreganj District in central Bangladesh carries water through his village. Kishoreganj is one of several areas in Bangladesh which has been affected by the presence of arsenic in its groundwater supply. To learn more, turn to page 10.
(D. Sacchetti/IAEA, August 2011)

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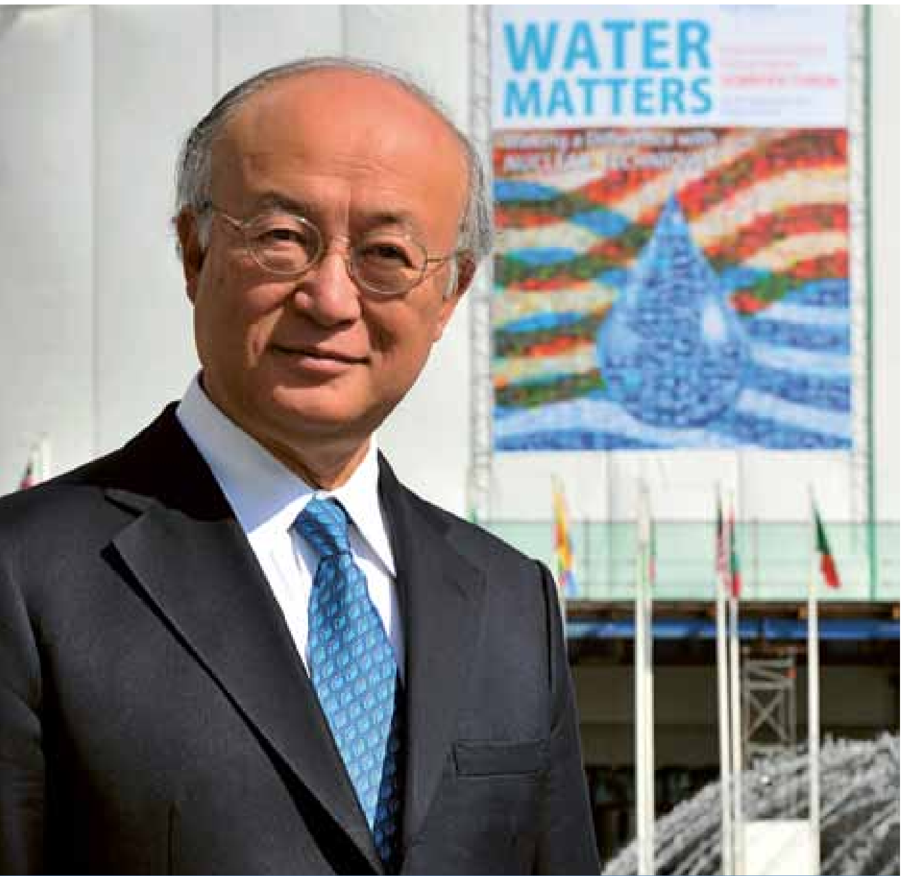
Why Water Matters

by Yukiya Amano



Nuclear techniques can help countries to manage their freshwater supplies and protect the environment.

The world faces acute water shortages. The current African drought is just the latest tragic example. One billion people have no access to adequate drinking water. Five million — mainly children — die each year due to water–borne diseases. Those numbers are expected to rise.

For over half a century, the IAEA has been doing everything it can to help, deploying its unique expertise in using nuclear techniques to understand and manage water. In more than 90 countries, our experts work with national counterparts to find, manage and conserve freshwater supplies and protect our oceans.

In the Santa Elena province in Ecuador, for example, the IAEA has worked with local partners to give over a quarter of a million people continuous access to fresh water for the first time. I saw this successful project myself in July 2011. Together with our partners, we investigate and measure the aquifers so that wells can be drilled in the right places and long-term sustainability of water supply is assured.

The IAEA is working with partners in Bangladesh to mitigate contamination of groundwater by natural arsenic, the worst such case in the world. The use of nuclear techniques made it possible to locate safe alternative supplies of water quickly and cheaply.

In Africa, where many farmers are confronted with arid growing conditions, water is becoming a rare commodity. The IAEA is working with 19 African countries to teach farmers to use appropriate, small-scale irrigation technology, supported by nuclear techniques, to make sure that every drop reaches the crops to produce greater yields.

The IAEA's experts also use nuclear techniques to protect the marine environments. Pollution threatens many of the world's seas and oceans, on which countless people depend for their livelihood. In 12 countries that ring the Caribbean, for example, the IAEA is helping to establish a laboratory infrastructure to identify sources of pollution and better protect seas and coastlines.

In order to raise awareness among the world's decision-makers about water issues, and about the enormous benefits of using low-cost nuclear techniques to address them, I decided that the September 2011 IAEA Scientific Forum should focus on this subject.

This issue of the IAEA Bulletin highlights the benefits of nuclear techniques in tackling global water challenges. It also describes our work with many national and international partners to improve global access to sustainable supplies of clean water and to protect the environment. I hope you will find it interesting and informative.

Yukiya Amano is Director General of the IAEA.

by Sasha Henriques

too little, too hard to find

Addressing the Global Water Crisis

(L.Potterton/IAEA)

Only 2.5% of the earth's water is fresh, not salty. Less than 1% of that tiny fraction is available for us to use. The rest is frozen in ice caps and glaciers, or occurs as soil and atmospheric moisture.

Almost all of that precious resource, the earth's accessible fresh water, is located underground — water that is hidden in the earth's crust and is often hard to access. This vital resource is poorly understood and poorly managed.

Water Crisis

This issue of management—understanding where water is available, who needs it, how to get it to them, and water's equitable and responsible distribution—is the crux of the problem.

When asked if there is a water crisis, Pradeep Aggarwal, head of the IAEA's Isotope Hydrology Section, said 'yes and no'.

Understanding where water is available, who needs it and how to get it to them is the crux of the problem.

(Photo: N.Ahmed/BAEC)

In high demand places, like urban areas and the arid and semi-arid areas of Asia and Africa, there often isn't enough water. But many low demand places have quite a lot.

"If we all begin to use water more conservatively however, there will be enough for everyone," he said.

Cities, Farms and Climate Change

"Nearly half of the world is going to be living in urban settlements in the next decade or so. Because a lot of people are living in a relatively small area, we need to provide water, all of which may not be available from nearby rivers or aquifers. Therefore, the urban water crisis results from the inability to provide a lot of water in a small area," said Aggarwal.

Freshwater's use in agriculture is also a major contributor to the problem.

"Agriculture uses almost 75% of all fresh water, most of which comes from groundwater systems and aquifers," he said. "If agricultural demand for water continues to grow at the rate at which it has grown in the past several decades, it will be difficult for us to provide enough water."

But there are technological developments which are leading to less water consumption, while maintaining or improving crop yields. These developments include genetic and non-genetic crop modification and drip irrigation.

"If there were to be further developments in agricultural technology, and if these were to be adopted more quickly, there might just be enough water to grow food to feed a growing world population."

Beyond expanding urban populations and more demand for food, there is the issue of climate change, which leads to too much rain at one time, causing flooding, rather than sufficient water going into the ground to recharge aquifers.

"Also, poor distribution mechanisms; inadequate protection of water sources to ensure they remain clean; and financial strain all conspire to increase governments' inability to provide sufficient potable water to their populations," said Aggarwal.

The need to understand and manage water is becoming more urgent for many countries. The IAEA, knowing how much water matters, is helping them do just that, using isotope hydrology.

Detective Work

Isotope hydrology helps scientists and governments get a handle on just how much water is in a particular location, where it's coming from and where it goes, what it picks up along the way and how it changes from liquid to gas, pristine to polluted.

Using its experience in nuclear technology, the IAEA has been involved in this type of research for more than 40 years. The Agency helps scores of Member States better understand their water resources.

Pollution

Essentially, isotopic techniques are used to understand how water moves. So countries also use isotopes to find out the source of water pollution.

Pollutants in water come from three main sources: agriculture, industry and human waste. A community might think its problems stem from lack of proper sanitation, when the real trouble lies with agricultural runoff into streams and rivers. Isotope hydrology helps them pinpoint and eventually solve their problems.

Let's Take Nitrogen as an Example

Nitrate is a common pollutant. Nitrogen has two isotopes: N-14 which is lighter than N-15. The ratio of N-15 to N-14 in fertilizers is different from the ratio in human or animal waste. Many fertilizers are made using nitrogen from the air, while humans and animals absorb nitrogen and change its isotopic ratio, through a biological process. By looking at the N-15 to N-14 ratio, a scientist can tell the source of the pollution.

Movement

Other pressing problems countries face include understanding where fresh water comes from, how much there is at any given time, and sometimes, most importantly, will this source continue to provide freshwater. Isotopes are used as tracers, providing the answers to these questions.

Radioactive isotopes such as tritium, carbon-14, and krypton-81 can be used to figure out how old groundwater is.

Because these isotopes decay over time, their concentrations decrease as the years go by. Higher concentrations mean "younger" water and lower concentrations mean "older" water. For example, groundwater with lots of tritium may be less than 50 years old, whereas groundwater with no tritium must be older.

Tritium works for groundwater younger than about 50 years, carbon-14 for waters up to several tens of thousands years old, and krypton-81 identifies waters that can be a million years old.

Understanding water's age gives scientists and governments a good idea of how quickly new water is getting into aquifers.

Knowing if one's water source is being replenished, and how quickly, helps governments plan how best to use the water that is now, and will be, available in the future.

Sasha Henriques, Division of Public Information.
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Assessing Water Needs

by Sasha Henriques

IAEA Water Availability Enhancement Project to Assess Global Water Management and Resources

As industrialisation and urbanisation increase, and the demand for food rises, fresh water stores are being depleted more quickly. Comprehensive information about water quality, how much there is, where it's located, as well as how this water is replenished, will prove invaluable when determining how best to allocate water resources to meet the needs of city dwellers, farmers and industry.

The IAEA Water Availability Enhancement Project (IWAVE) will help Member States identify and fill gaps in existing hydrological information, enabling national experts to conduct independent assessments, as well as continually update hydrological information.

IWAVE will also help countries interpret water resources data, and use advanced techniques to simulate hydrological systems for resource management.

Oman, the Philippines and Costa Rica are now participating in the pilot phase of the IWAVE project, which should build on, and complement, other international, regional, and national initiatives to provide decision makers with reliable tools for better management of their water resources.

"By becoming more knowledgeable about your own resources, not only do you improve your water use and availability, but you are also better able to deal with and cooperate with your neighbours who share your resources," said Charles Dunning, Water Resources Advisor in the IAEA's Isotope Hydrology Section.

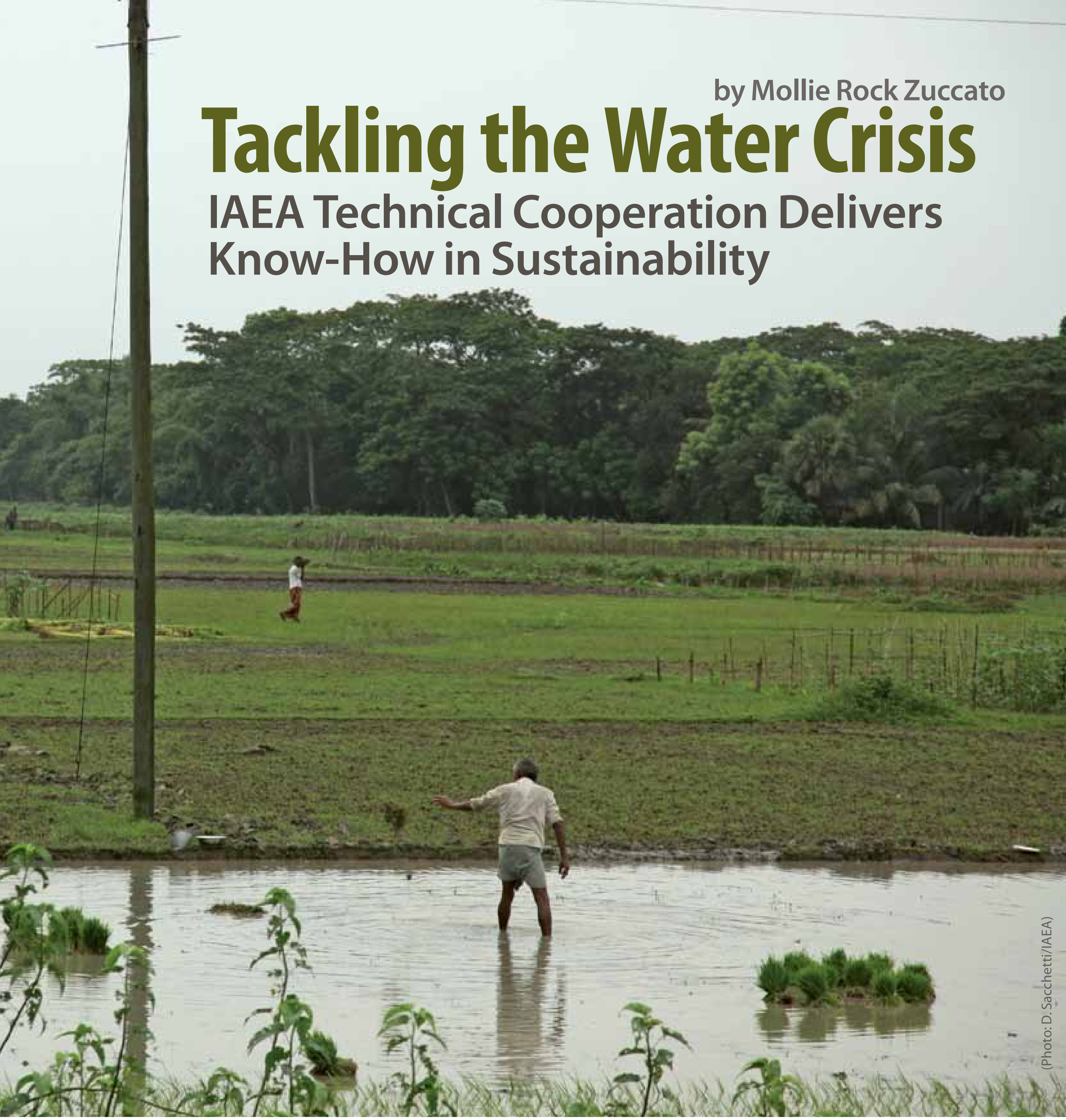
Sasha Henriques, Division of Public Information. E-mail: S.Henriques@iaea.org

Comprehensive information about water quality, will prove invaluable when determining how best to allocate water resources to meet the needs of city dwellers, farmers and industry.
(Photo: P.Pavlicek/IAEA)

by Mollie Rock Zuccato

Tackling the Water Crisis

IAEA Technical Cooperation Delivers Know-How in Sustainability



(Photo: D. Sacchetti/IAEA)

In a world facing severe challenges to water resource availability, nuclear technology helps manage and make the most of natural resources. Environmental degradation and a lack of clean water pose fundamental challenges to sustainable development. Socioeconomic advances cannot be sustained without clean air to breathe, safe water to drink, healthy soils for crops and livestock production and a clean and stable environment to support work and life.

The IAEA's technical cooperation programme helps Member States to achieve their development priorities while monitoring and protecting the air, earth and oceans.

Managing Groundwater

Groundwater is the primary source of drinking water for half of the world's population. It is important that developing countries can protect and optimize what limited groundwater resources they have. Groundwater that has been contaminated due to land use activities affects public health and the environment. Industry is the greatest source of water pollution for developing countries. Rain runoff, especially flood water, is another major polluting agent because of the many different substances that it carries into freshwater systems.

IAEA technical cooperation projects promote the use of isotopic techniques to understand the source, extent and behaviour of water resources, as well as their vulnerability to pollution. Isotope hydrology also helps to identify the origin and extent of pollution or saline water intrusion, and provides valuable inputs for sustainable water resource management.

IAEA projects support the development of comprehensive national and transboundary water resource plans for domestic, livestock, fishery, irrigation and other water uses, and help Member States to develop regulations, procedures, standards, minimum requirements and guidelines for sustainable water management. Regional monitoring networks and databases on isotopes and the chemical constituents of surface water and groundwater can also help to improve water resource management.

Additionally, radiation processing technology, in combination with other techniques offers improved environmental safety through effective treatment of wastewater, and supports the reuse of treated wastewater for urban irrigation and industrial purposes.

Conserving Agricultural Water

Nearly three-quarters of the freshwater used annually is consumed in sustaining agriculture. In forty years, that consumption will need to increase by 50% to meet rising food demand. At the same time, indiscriminate use and evermore frequent extreme weather events, such as droughts, shrink our access to freshwater. Effective conservation is thus an urgent priority for both rain-fed and irrigated farming systems. IAEA technical cooperation projects apply nuclear technology to develop efficient and cost-effective irrigation methods that improve yields and the effectiveness of soil and water conservation strategies in retaining water and applied nutrients for food production under both rain fed and irrigated agricultural systems.

Harmful algal blooms in oceans can severely affect local and international trade. The IAEA helps in finding quicker and more accurate means of detecting the presence of toxins in marine life.
(Photo: D. Sacchetti/IAEA)

Improving Crop Growth

To be certain that every drop of rainwater or irrigation water reaches crops, isotopic techniques are used to optimize soil-water-cropping practices and fertilizer technologies. This research improves the soil's fertility and quality to grow more nutrient-rich and higher-yielding crops. Carefully dosing and placing fertilizers reduces waste, protects the environment and cuts costs while increasing plant production.

Monitoring and Protecting the Oceans

Marine pollution is a serious threat to marine creatures and habitats. Pesticides, toxic chemicals and heavy metals that enter the marine food web can lead to mutation, disease and behavioural change, and eventually end up in the food we eat. Trade in fish and seafood depends on a country's ability to determine the quality of foodstuffs.

IAEA technical cooperation projects help Member States to establish or strengthen analytical laboratories that can measure environmental radioactivity and pollutants in the oceans or in marketable foodstuffs. Other projects build national capacities to carry out marine environmental studies using nuclear analytical and radiotracer techniques that can track the movement of heavy metals and pollutants in the marine environment. By using such techniques, Member States can enhance their understanding

Isotopic techniques also identify soil-water-cropping practices and fertilizer technologies that improve soil fertility status and soil quality for more nutrient-rich and high-yielding crops.
(Photo: L. Potterton/IAEA)

of the earth's oceans, and their ability to manage and protect marine resources.

Identifying Harmful Algal Blooms

In the ocean, harmful algal blooms (HABs), often referred to as red tides, can severely affect local and international trade. The IAEA helps Member States by finding quicker and more accurate means of detecting the presence of toxins in marine life. Early warning programmes provide important information about HABs to fishermen and consumers.

What the IAEA Technical Cooperation Programme Does

Training courses and workshops cover topics such as marine contamination analysis, the distribution of contaminants, soil fertility and crop nutrition, soil and water conservation, soil-water salinity management, the establishment of permanent regional monitoring station networks and equipment use and methods customized to regional needs.

Expert assistance makes available on-the-spot training in a developing country by a recognized expert. When complex equipment is supplied to a country, the project usually includes the visit of an expert to train the staff in the operational and technical aspects of the instrument.

Training and fellowships prepare local personnel to take over the responsibilities of soil-water-crop management, air quality and water resource assessment, and freshwater/marine water environmental impact evaluation in Member States.

Conferences, symposia and seminars are designed for the exchange of ideas between scientists from various countries.

Equipment and materials provided by the IAEA are used to establish or enhance sustainable environment, water resource assessment and land and agricultural water management.

Partnerships

Technical cooperation projects involve collaboration between governments, IAEA partners and Member States, keeping in mind priority national developmental needs where the IAEA has a unique role to play, where nuclear technology has a comparative advantage or where the IAEA can add value to services from other development partners. The IAEA strives to establish partnerships and working relationships through consultations and interactions with United Nations system organizations and other potential partners. Collaborative work ensures the coordination and optimization of complementary activities and informs relevant UN organizations of the developmental impacts of the TC programme.

Many activities are carried out in partnership with international organizations, such as the United Nations Environment Programme, the United Nations Development Programme, the International Maritime Organization, the Global Environment Fund, the Food and Agriculture Organization, the Consultative Group on International Agricultural Research, Inter-American Institute for Cooperation on Agriculture, Alliance for a Green Revolution in Africa, the Intergovernmental Oceanographic Commission and the United Nations Educational, Scientific and Cultural Organization, National Oceanic and Atmospheric Administration and the United Nations Industrial Development Organization.

Mollie Rock Zuccato, Department of Technical Cooperation.
For more information, visit: tc.iaea.org

Optimal Results by Juanita Perez-Vargas

IAEA Supports Water Research in Latin America

Jane Gerardo-Abaya, Programme Management Officer for Latin America in the IAEA's Technical Cooperation Division discusses in this interview the Agency's support in handling water challenges in Latin America and the Caribbean:

Gerardo-Abaya: The IAEA extensively studies this problem because the region is severely affected by inadequate safe water supplies. The region has large water resources, however, most population centres are located in coastal areas where water availability is limited or vulnerable to contamination due to seawater intrusion into aquifers when there is excessive water extraction.

The population is heavily dependent on the use of groundwater which is generally limited. And while a small portion of the urban population has no access to water, a large portion of rural areas have no access to drinking water.

This also has to do with water which, although at times available, is contaminated. Access to sanitation is a problem for the region, especially where wastewater remains untreated, and can reach the groundwater, contaminating this scarce resource. In addition, agriculture can be a problem because pesticides and fertilizers eventually flow into the groundwater or surface water. It is important to note that agriculture uses water largely for irrigation, livestock and aquaculture production, comprising 70% of global water consumption.

How does the IAEA help Member States address water supply problems?

Gerardo-Abaya: The IAEA enhances Member States' ability to acquire a scientific understanding of the occurrence, flow and water dynamics and to understand the mechanisms of contamination. This is achieved by using isotope hydrology that adds value in obtaining conclusive results, which are not normally achievable with traditional hydrological techniques alone.

There is a growing need for scientific information among decision makers to support effective policy formulation and resource management. In this area, the IAEA's support for Member States' scientific research is very valuable.

Juanita Perez-Vargas

Specifically, the IAEA provides both laboratory and field training. The IAEA teaches best practice in sample collection, analysis, and data interpretation to be certain we can understand the processes at work. The IAEA also provides expert assistance and supports upgrades for Member State laboratories to help them achieve optimum performance in research.

What kind of results have these projects achieved in Latin America ?

Gerardo-Abaya: Seven coastal aquifers and their characteristics are now under study by the authorities, nuclear institutions and universities in Argentina, Costa Rica, Cuba, Ecuador, and Uruguay. Our specific achievements have been to increase the number of qualified specialists in groundwater management, as well as increasing research capacity in laboratories and in the field thanks to equipment provided by the IAEA.

Juanita Perez-Vargas, Division of Public Information. E-mail: J.Perez-Vargas@iaea.org

Complex Science Saving

Employing a traditional technique, these men dig a shallow tube well. However, since many of Bangladesh's shallow water supplies are affected by arsenic, this water is unsafe to drink.

Bangladesh's arsenic crisis came to light in 1993, after a number of people in villages across the country fell ill, and it was confirmed that their main source of drinking water — groundwater from the deltaic basin — was contaminated with arsenic.

In the early 1970s, most of Bangladesh's rural population got its drinking water from surface ponds and nearly a quarter of a million children died each year from waterborne diseases. The provision of tube well water for 97% of the rural population brought down the high incidence of diarrheal diseases and halved the infant mortality rate. Paradoxically, the same wells that saved so many lives were later found to pose a threat due to the unforeseen hazard of arsenic.

The arsenic contamination in Bangladesh has natural causes: arsenic is mobilized into the groundwater by geological and biological processes, rather than human activity.

Because there is no easy way to remove or stop the pollution, scientists sought to find out where the arsenic is, how it´s getting there, and how old the water is. This way they could identify the arsenic-free aquifers. In collaboration with the Bangladesh Atomic Commission, the IAEA provided the scientific analysis to support the project.

Isotope hydrology, which is used to track the movement of water, played a significant role in understanding and addressing the problem.

Since 1999, the IAEA has supported arsenic mitigation projects at the local and national level by helping institutions use isotope techniques to get accurate information on arsenic contamination much more quickly and cheaply than is possible with non-isotope techniques.

The data also offers a precise assessment of groundwater and aquifer dynamics. Thus helping to determine if deep aquifers will remain

Lives in Bangladesh

by Sasha Henriques

arsenic free over the long term, if they are developed as alternative sources of freshwater, and how other deep aquifers may have been contaminated through mixing of deep and shallow reservoirs.

"When arsenic was identified in Bangladesh's groundwater, the IAEA helped us to start our isotope hydrology project to find solutions to mitigate the arsenic problem," said Nasir Ahmed, head of the Isotope Hydrology Division of the Bangladesh Atomic Energy Commission. "Through this collaboration with the IAEA, we were able to determine where safe water could be found."

To conduct isotopic analysis independently, the IAEA worked with Bangladeshi counterparts to build new laboratory capacity. "Through our IAEA Technical Cooperation project, we have been able to develop the isotope measurement facility here in Bangladesh," said Ahmed.

In the past ten years, 12 scientists/engineers were trained through 7 fellowships, 5 scientific visits and 6 regional training courses.

Isotope hydrology is still being used in Bangladesh to determine the movement of groundwater, where aquifers are being recharged and therefore the rate at which it can be sustainably used, how complex aquifer systems connect and mix with other water bodies, and how vulnerable they are to contamination.

Sasha Henriques, Division of Public Information. E-mail: S.Henriques@iaea.org.

Photos: Dana Sacchetti, Division of Public Information.

Left: Using training and equipment provided by the IAEA, the Bangladesh Atomic Energy Commission (BAEC) analyzes water samples in its laboratory. Isotope hydrology can help reveal the age, location and movement of safe drinking water.

Right: Nasir Ahmed, head of BAEC's isotope hydrology laboratory, conducts a full analysis of water taken from a well. Ahmed's team works to help decisionmakers find safe drinking water.

Water Fingerprints

Water from different places acquires a distinctive 'fingerprint' that nuclear techniques, so-called isotope hydrology, can make visible. When water evaporates and condenses the concentration of oxygen and hydrogen isotopes in water changes.

Isotopes are naturally occurring atoms of differing atomic weight. Water vapour rising from the oceans carries a lower concentration of heavy isotopes than sea water. When the resulting clouds release water, the heavy isotopes fall out first.

As clouds move inland, their isotopic composition again changes, and the water acquires individual and characteristic 'fingerprints' in different environments. There are other isotopes in rainwater whose concentration decreases with time. These isotopes in surface or groundwater can be measured to determine the "age" or residence time of water within a particular water body.

IAEA Helps Parched Santa

The thirsty residents of Manglaralto on the Santa Elena peninsula on Ecuador's southern central coast have been feeling a gush of relief. A joint IAEA project to find water in the area has led to an abundant water flow where before there was barely a trickle.

At the Chemical Institute of the Escuela Superior Politécnica del Litoral, the IAEA's partner in isotope hydrology, Fernando Morante, PhD. Head of the Laboratory, Priscila Valverde and Byron Galarza, conduct research in the water and environmental laboratory, February, 2010, Guayaquil, Ecuador.

"Thanks to studies ESPOL (the university, Escuela Superior Politécnica del Litoral) has given us and to adaptation of the aquifers, we now have four more wells. Since 2009, we have had water 24 hours a day," says Miler Muñoz, president of the local group Junta de Agua Manglaralto (the Manglaralto regional water board). Prior to this, there were only three wells supplying water for a limited number of hours per day.

"We have received several seminars from the IAEA and expert visits. This is our salvation because we need water in the area. The seminars have helped us to find solutions to obtain water.

"It has benefitted us. We have a permanent water supply. For example, the cabins where people sell food at the seaside could not operate because they did not have water. We have trained ourselves, and requested outside help…to solve our problems related to groundwater, Muñoz said."

The problems facing the Santa Elena Peninsula and the 250 000 inhabitants of the area — 100 000 in the countryside are particularly hard hit — are not uncommon in many parts of the world. The study area is characterized by arid to semi-arid tropical climate conditions, where more water is lost through evaporation and transpired by plants,—so-called evapotranspiration— than can be replaced through annual precipitation. Rivers are seasonal and recharge to aquifers is limited, so dependence on groundwater is rising. Local aquifers are affected by seawater intrusion, with the salinity of soil water and groundwater increasing due to intensive pumping. In some areas the groundwater is no longer fit for human consumption, and the situation has been distressing for both residents and farmers.

ESPOL applied for an IAEA Technical Cooperation project and the first project — implemented in collaboration with local groups — began in 2007. The IAEA has contributed to training, provided experts, equipment, mapping tools, as well as a solid foundation for the project.

But the project has been able to accomplish something beyond a standard water assessment.

"For the first time it belongs to them," says Luis Araguás Araguás, a scientific officer from the IAEA's Isotope Hydrology Section involved in the project. "It is not something the government does for them; this is why they are deeply committed."

"We have done a standard assessment of water resources in the area, and are still in the earlier stages of characterization. From a scientific point of view it is not extraordinary," says Araguás Araguás. "What makes it different is the social component."

What is different is that ESPOL has equipped the communities at a local level to test their own water quality. IAEA experts informed local people about the science of isotope hydrology. "Wells are only drilled after ESPOL has tested a site," says Araguás Araguás. "There is a kind of ownership by the community, and they are interested in monitoring. Now the community asks ESPOL to come. ESPOL has produced specific management instructions for each sector."

Elena Find Water

by Maureen MacNeill

The communities have been integrated in this programme, says Emilio Rodríguez, president of the local Junta Regional de Agua Olón (the Olón regional water board). "They are an active component of this process. These studies are not easy to perform due to high costs and lack of equipment."

Many changes have occurred as a result of two IAEA projects underway in the peninsula, according to Gricelda Herrera Franco an ESPOL counterpart. "First the communities worked in association with the university and they use technology and techniques. The communities then worked on the projects and they developed a new culture for working in teams. Finally, the communities now have a permanent water supply (365 days a year). Before this was not possible.

"This programme is for everybody in the community. With a permanent water supply they think about possible business for tourism development in the areas. They also believe in new opportunities for agriculture. They feel very happy and have confidence in themselves. They see themselves as entrepreneurs."

IAEA Director General Yukiya Amano visited the site in July 2011 and was impressed by the results he found there. He told the local counterparts, "In our culture we say one arrow is weak, you can bend it, you can break it. If there are two it's very difficult. If three are combined, you can't break it, it's very strong. We now have the IAEA, an international organization, we have ESPOL, a university, and we have the local community of Santa Elena. With the cooperation of these three partners, I am very certain we can have a successful project."

The project provides solutions, yet the main challenge lies ahead, to ensure that the results the communities have achieved can be sustained with the support of ESPOL and IAEA.

Maureen MacNeill, Division of Isotope Hydrology.
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Photos: ESPOL

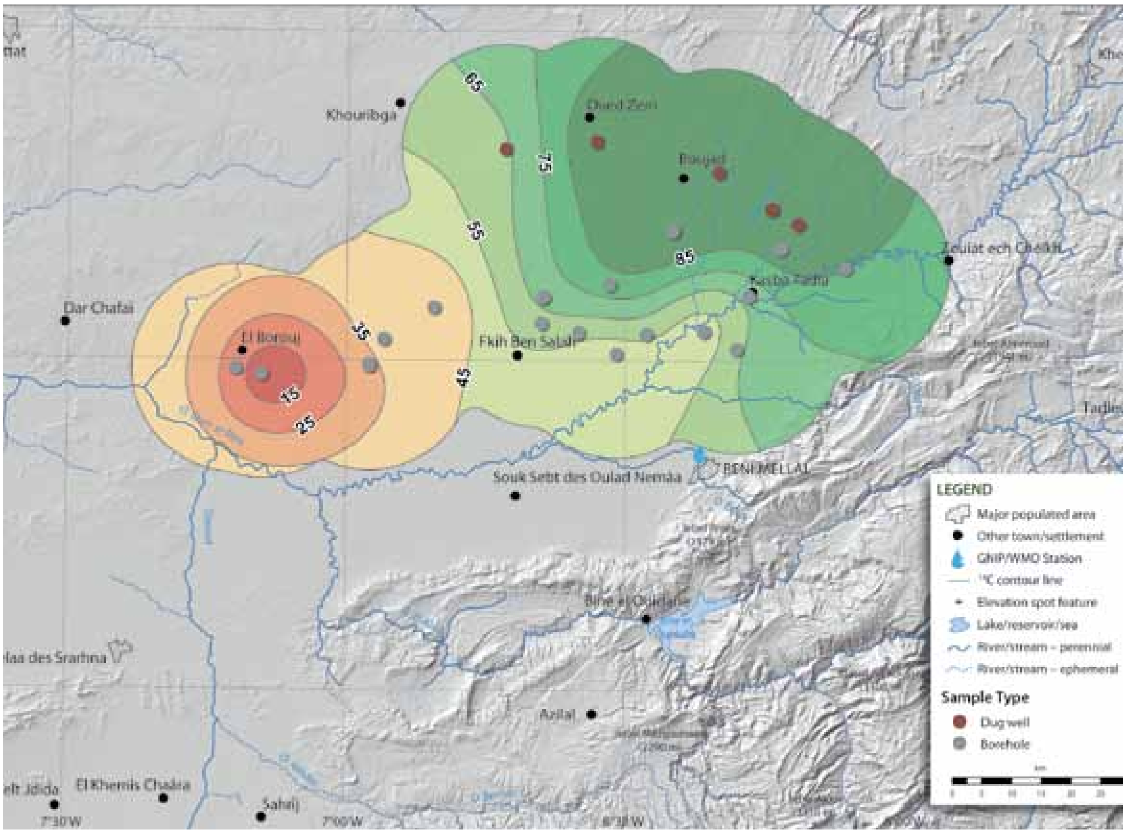
Miller Muñoz and Victor Hugo Yagual show the IAEA Director General Yukiya Amano (taking water from the tap) a new well whose sustainable siting was supported through the IAEA's expertise in isotope hydrology and its Technical Cooperation Programme.
(Manglaralto Commune, Santa Elena Province, Ecuador, July 2011.)

People queue for water at the communal well in the Valdivia Commune, Santa Elena Province, Ecuador.

Treasure Maps

by Peter Kaiser

The IAEA's Hydrological Atlases Reveal Hidden Resources



The plate from the *Hydrological Atlas of Morocco* showing water that is only minimally recharged as red areas. The green areas indicate water that is recharged.

The IAEA's water experts have published a unique series, the Atlas of Isotope Hydrology, including volumes devoted to regions of Africa, the Americas, as well as Asia and the Pacific, and the first national Atlas that profiles Morocco. Pradeep Aggarwal, the Isotope Hydrology Section Head, explains why the Atlases were produced and how they help water planners ensure access to fresh water for the future.

Above, the plate from the *Hydrological Atlas of Morocco* shows older water that is only minimally recharged as red areas, while the green areas indicate water that is recharged. Water that is not recharged, is considered to be water that is mined as an exhaustible resource.

The Guarani aquifer, one of the largest fresh water reservoirs in the world, stretches between Argentina, Brazil, Paraguay and Uruguay. In a plate from the *Hydrological Atlas of the Americas* (see page 16), the sampling points located in the four countries overlying the aquifer are shown.

When did this global project begin?

We started to compile information in the hopes of producing an atlas about ten years ago. We wished to bring together data that already existed, much of which was available in our archives, yet was rarely seen or used. We invested a considerable amount of time searching for data in the IAEA and external archives. We published the first volume on Africa in 2007. Over 100 countries' data are included in this series.

Had anyone ever tried to integrate the available water databases into one cohesive document like the Atlas before this effort began?

No. No one had and that was the driving force behind this effort. For more than 50 years, the

IAEA has been publishing the Global Isotopes in Precipitation databases, which are used to understand hydrology. The Atlases contain data collected mainly through IAEA projects conducted in developing countries. These data were not available to anyone outside these projects. It was a great concern to us that the countries whose water systems were studied could not access this data.

As a result, when we visited countries in the 1990s and early 2000s, we would come upon a situation in which no one knew whether studies had been previously conducted, thus projects were conducted without understanding what was done in the past. If we did learn that a project had been conducted previously, the data was often no longer accessible. Therefore, to be able to offer Member States a resource that can be used to achieve progress, rather than treading water by repeating studies that simply collect similar information, as well as to offer researchers around the world comprehensive data, we decided to produce these Atlases to advance the science of hydrology.

What insights can be gained from a database of isotopes in precipitation?

Isotopes in precipitation help us understand climatic systems. The product of a hydrological system is precipitation. So, we are trying to understand atmospheric processes by using isotopes in precipitation, which tell us how climate influences precipitation, or how precipitation results from a certain climate.

Once precipitation reaches the surface, it then enters lakes or rivers or the ground water systems. If you want to understand how your rivers function, if you want to know how water supplies will be impacted by climate change, or by land use changes, or if you need to know whether you can control the pollution that results from agricultural activities, you have to know where the water comes from and how it flows through the hydrological system.

The same holds true when trying to understand the underground water systems. As with rivers and lakes, when studying aquifers, you need to know where the water came from and how the aquifer is recharged and how quickly. All of that information relates back to precipitation. And it is isotopes that allow us to trace precipitation.

When an expert views these maps, what can they decipher from these symbols and figures?

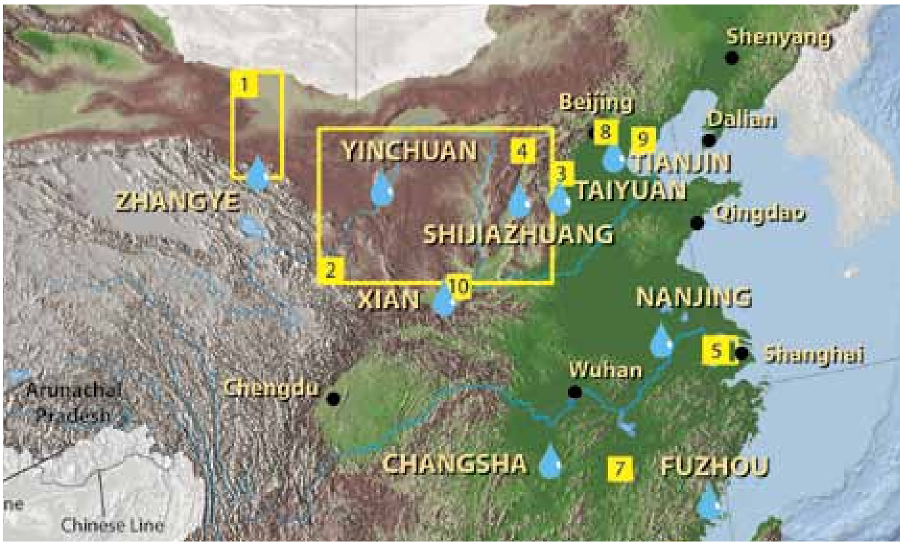
For instance, if you compare the isotopic data in groundwater with precipitation at a given location, you can determine whether the underground reserves are being recharged and can help identify the source of the water that recharges the reserve, such as a local source or a distant mountain. If the precipitation and the groundwater data do not match, regardless whether you compare local sources or distant sources upstream in the mountains, then potentially the underground reserve was recharged in the past by a very different climate system.

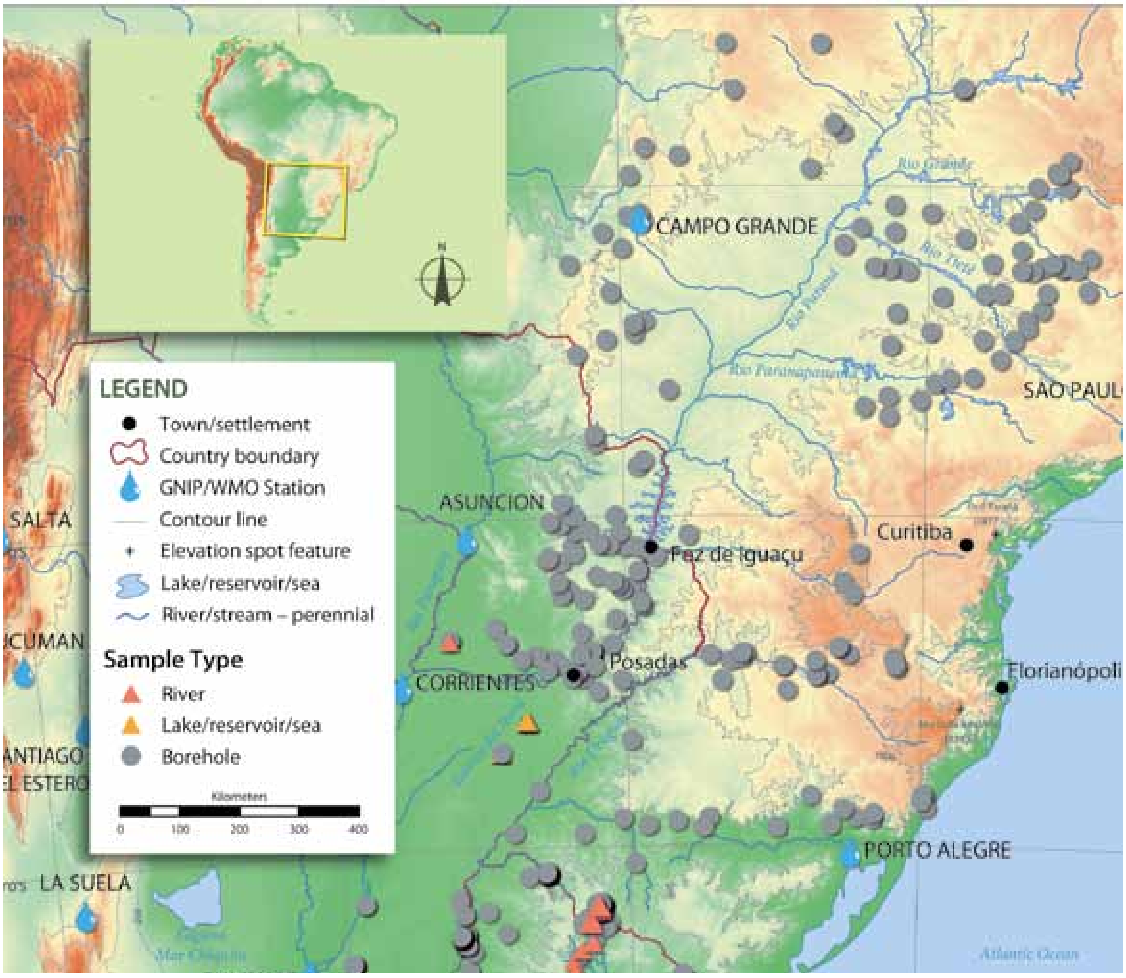
Therefore the isotopic database and the Atlas can help you understand a vital process for water management, whether an underground reserve is recharging and how quickly.

Does this Atlas help planners find water and use it sustainably?

Yes, it will. The primary purpose for using isotopes is to acquire information about the water system in a timely and cost-effective manner. I could spend 50 years in a country, measuring the rain and water levels in rivers and aquifers, and I would have a reasonably accurate picture of what happens to water in that system. Or, I could review the isotopic composition of the water now and acquire the same level of understanding fairly quickly.

A detail from an isotopic overview map of China taken from IAEA's *Hydrological Atlas of Asia*.





From the *Hydrological Atlas of the Americas*, this plate displays the Guarani aquifer, one of the largest fresh water reservoirs in the world. The map provides information about sampling points in the four overlying countries.

If you have an Atlas, it gives you instantaneously a hydrological picture of a large area over a long time period. You can use those data to refine future water investigations to garner more accurate insights into this complex system, and, as your investigations proceed, the data can be placed in a cohesive framework which then gives you an understanding of the inter-relationships between systems. The Atlas helps you deepen and broaden your understanding of water systems. The Atlas facilitates the investigations of water.

If planners invest in learning how to interpret isotopic information, they will save money by avoiding drilling wells that will run dry or not deliver safe water. That is the purpose of the Atlas: we build these "larger-than-local" maps to show where the water is located and how it flows between different rock systems so that you have a better ability to tap these waters sustainably and economically.

Is the Atlas a "treasure map"?

To some extent, because otherwise you would have to make physical measurements of all of those systems in the hopes of acquiring the same understanding that you can acquire by studying isotope data. This is not a panacea – additional work, investigation and investment is needed to understand these "treasure maps". They are a valuable resource that offer an instant picture of how the underground system is configured, how it works and where to focus your investigation and thus speed your search for the treasure you seek or the knowledge you need to protect the water resources.

Where do you wish to go from here?

We now hope that the series will expand to include many, many national Atlas projects that will be carried forward by our partners at the national level.

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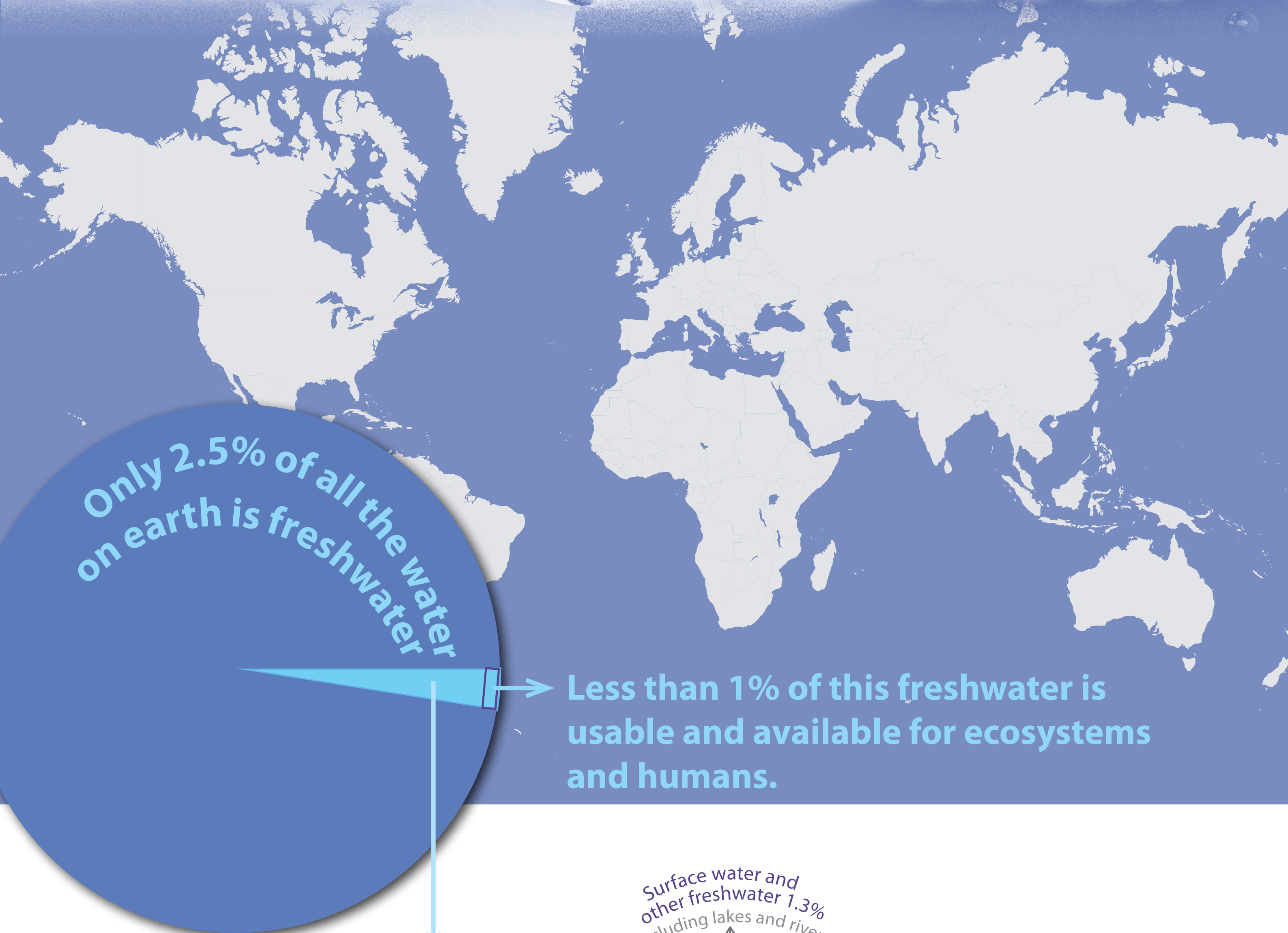
all about Water

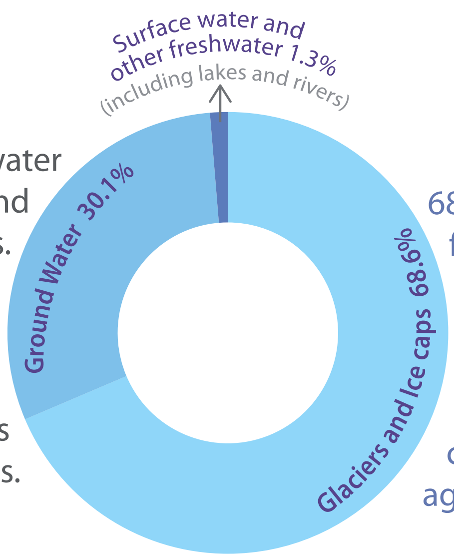


Less than 1% of this freshwater is usable and available for ecosystems and humans.

Of this fraction, one third is groundwater — hidden in the Earth's crust and often hard to access.

This vital resource is poorly understood and poorly managed.

And as little as 0.3% of freshwater is easily accessible in lakes and rivers.

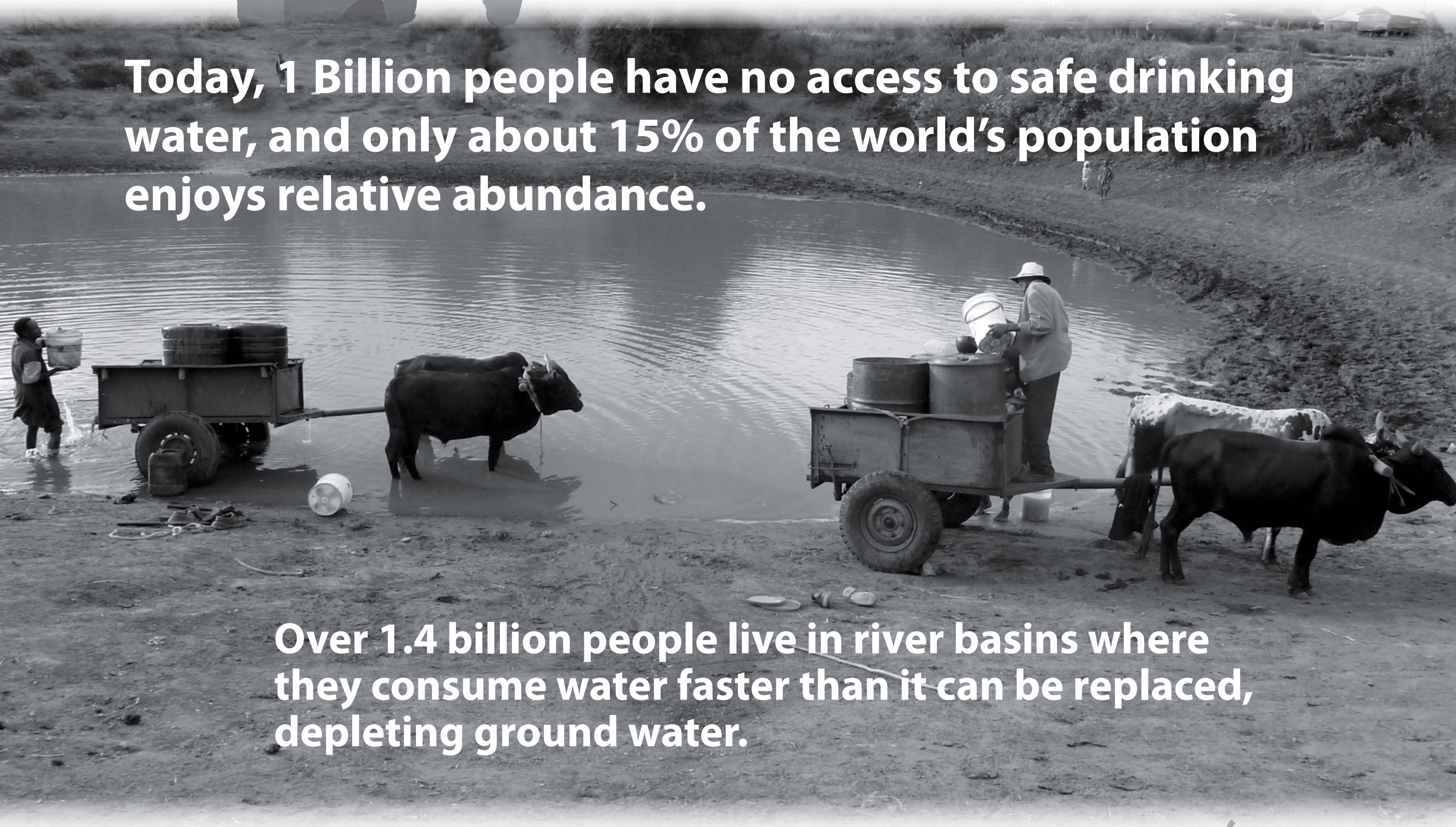


68.6% of the world's freshwater is in the form of ice and permanent snow in mountains. Frozen water is unavailable for consumption or use in agriculture.

accessability

12 of the 15 most water scarce countries are located in the Middle East and North Africa.

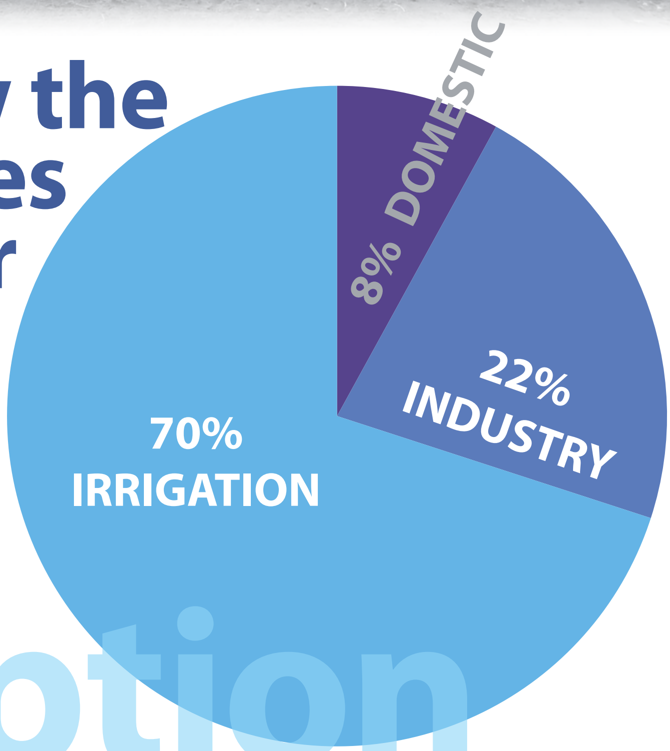
By 2025, 1.8 billion people will be living with absolute water scarcity.



Today, 1 Billion people have no access to safe drinking water, and only about 15% of the world's population enjoys relative abundance.

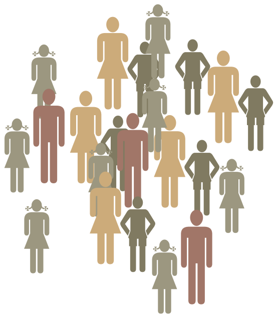
Over 1.4 billion people live in river basins where they consume water faster than it can be replaced, depleting ground water.

How the world uses Freshwater



consumption

urbanisation



In 1900

less than 15% of the world's population lived in cities.

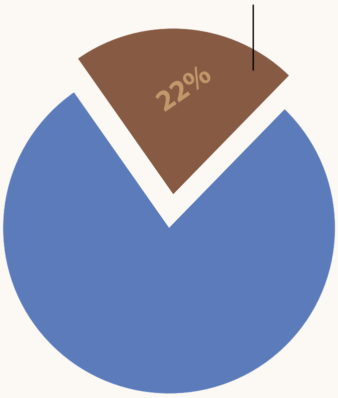
In 2011

this figure has reached 50%.

For the Millennium Development Goal related to drinking water to be met by 2015, **961 million urban dwellers must gain access to an improved water supply.**

industry

Industries use up 22% of world's freshwater

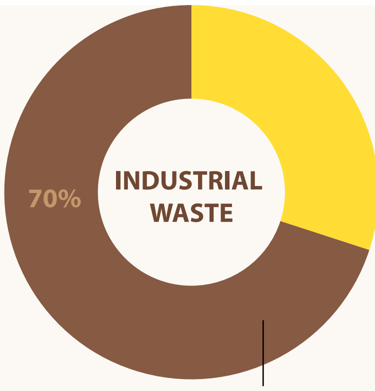


High-Income Countries

59% of total water use is for industry.

Low-Income Countries

Only 8% of total water use is for industry.



In developing countries, 70% of industrial waste is released untreated into waters, polluting the usable water supply.

Water Needed to Produce Food

Food Item	Unit	Global Average (in litres)
Chocolate	1 kg	24, 000
Beef	1 kg	15, 500
Cheese	1 kg	5, 000
Pork	1 kg	4, 800
Olives	1 kg	4, 400
Chicken	1 kg	3, 900
Rice	1 kg	3, 400
Groundnuts (in shell)	1 kg	3, 100
Dates	1 kg	3, 000
Mango	1 kg	1, 600
Sugar (from sugar cane)	1 kg	1, 500
Bread (from wheat)	1 kg	1, 300
Banana	1 kg	860
Milk	1 glass (250 ml)	250

agriculture

- **In rain-fed agriculture, up to 85% of rainwater is lost before it reaches crops.**
- **By the year 2050, 50% more water will be needed in agriculture to feed the growing world population.**

marine pollution

Coastal zones support 60% of the world's population, providing food, income and living space.

Every day, 2 million tons of human waste enter water courses.

Oceans and seas receive the brunt of human waste — a serious threat to marine creatures and habitats.

working on solutions

iaea

A key requirement for assuring adequate water supplies and their sustainable management is to improve the assessment of water resources.

The IAEA deploys its expertise in nuclear techniques in more than 90 Member States to help locate, manage, and conserve freshwater, as well as to protect the oceans.

The IAEA databases broaden our understanding of water systems, oceans and climates.

The IAEA's water experts help developing countries through technical cooperation, by providing advice, materials, equipment, and training, as well as offering fellowships and research projects.

Sources: UNEP, World Water Assessment Programme (WWAP), Global Environment Outlook: Environment for Development (GEO-4), Human Development Report 2006, World Business Council For Sustainable Development (WBCSD), Food and Agriculture Organization of the United Nations (FAO) and UN-Water, Young People's Trust for the Environment, *The Water Footprint of Food (2008)*, Professor Arjen Y. Hoekstra, University of Twente, the Netherlands, *Water For Food*, The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas), Sweden.

Photos: Louise Potterton/IAEA (pg 18); iStock (pg17); Nancy Falcon Castro/UNIDO (pg20).

Improving Farming with Nuclear Techniques

by Sasha Henriques

Soil erosion, land degradation, the excessive or inappropriate use of fertilisers in agriculture and poor water quality are threats to the environment and hamper development.

IAEA projects apply nuclear technology to evaluate these risks and find ways to make better use of water and soil resources. Many countries have benefited from this programme, including Qatar, Chile, Kenya, Turkey, Vietnam and Bangladesh.

Qatar is one of the 10 most water-scarce countries in the world and all its arable land is irrigated with groundwater. But, more than half of the water being used doesn't reach the crops, evaporating from the soil to the atmosphere. As more groundwater was used for irrigation, and levels fell, seawater and saline water from deeper aquifers intruded on the supply of fresh groundwater.

Isotopic techniques were used to determine the most efficient way to use saline groundwater and treated sewage water through drip irrigation.

Drip irrigation reduced the amount of water needed by up to 30%, compared to sprinkler irrigation.

There are now plans to use 100 million m^3 of saline groundwater with 60 million m^3 of treated sewage water annually, which will effectively increase agricultural acreage eleven fold.

Nearly 60% of arable land in Chile is affected by erosion, and in Central Chile, a shortage of flat land has increasingly compelled wine growers to plant vineyards on hillsides which eventually pollutes water downstream. Three consecutive IAEA technical cooperation projects were undertaken in Chile to investigate this problem. A fallout radionuclide was used to determine the extent of soil erosion and resulting water pollution. The research showed that current vineyard management practices are untenable.

So there are now plans to investigate the use of permanent ground cover between vines to effectively minimise soil erosion and water runoff on slopes and hence improve downstream water quality. Emilio Sanchez from the La Roblería vineyard in Apalta says, "The vineyard associations have been open to embrace nuclear research techniques as it has been a win-win relationship for the farmers of the region."

In Kenya, agriculture is the second largest contributor to gross domestic product, with 70% of the population working in the sector. Yet the majority of farmland is arid or semi-arid, with low and erratic rainfall. And food production is low with frequent crop failures. The IAEA worked with the local scientists to develop small-scale, low-cost drip irrigation technologies for poor farmers.

Isotopic techniques were used to determine the most efficient way to use saline groundwater and treated sewage water through drip irrigation.

These technologies, perfected by the Kenya Agricultural Research Institute (KARI), are currently being transferred to smallholder farmers for use with high-value crops like cucumber, tomato, kale and lettuce. An example is a project that provides Maasai farmers at Namanga on the Tanzanian border hands-on training in drip-irrigation techniques (see page 23). KARI now provides technical expertise and know-how on agricultural water management to 23 African countries.

Turkey is the world's 5th largest potato exporter. The main challenge farmers encounter is to use water and fertilisers more efficiently by applying irrigation water mixed with fertilisers, also known as fertigation, to the right place, at the right time and in the appropriate amount. Using drip irrigation significantly reduced the amount of water and fertilisers that were needed. This is having a major impact on Turkey's potato production, yielding substantial savings for farmers.

Vietnam has also been affected by erosion, loss of soil nutrients, as well as water and fertilizer use efficiency problems. They sought the IAEA's help. Compound-specific stable isotope techniques were used to identify areas of land degradation. The findings of the project have been used to raise farmers' awareness and to help them adopt strategies to mitigate the impact of typhoons on agriculture in north-western Vietnam.

Soil salinization is a major threat to crop production in Bangladesh; such that about 90% of potentially arable lands in the coastal area remain unused during the dry season. Improved water management practices through drip irrigation, coupled with the identification of saline-tolerant crop varieties during the project, have enabled farmers to introduce and harvest a second crop, in addition to aman (paddy) rice, on potentially up to 2.6 million hectares of highly fertile coastal lands. This could, for example, possibly add an additional 4 million tonnes of wheat to the national bread basket.

Abdul Aziz, who is a farmer from Noakhali, Bangladesh, says, "I used to leave my family in the village and go to Dhaka in search of a job because I could not grow any crop from August to April due to the high salt content in the soil. Now, I earn about US $2000 per hectare each year from the cultivation of newly introduced groundnuts and wheat."

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Making the Most of It

by Peter Kaiser

Radiation technology cleans polluted water for re-use

Today, cities host rapidly growing populations and expanding industries. The flow and severity of the pollution that transforms freshwater into wastewater is increasing as a result. Common chemical contaminants in water include persistent organic pollutants, petrochemicals, pesticides, dyes, heavy metal ions, as well as excreted pharmaceuticals. These complex compounds are difficult, often impossible, to remove or degrade using conventional means, and remain in the water to pose new and worsening health risks. Neutralizing these risks makes wastewater management challenging and more expensive. Cities and industries need cost-competitive solutions to treat water to be able to reuse it responsibly.

Frequently, cities face a water shortage, which they hope to alleviate by treating wastewater so that it can be utilized for tasks such as fire fighting, street cleaning, urban park and horticultural irrigation, industrial cooling and laundry, and boiler water for heating that do not require drinking-water quality. This "reuse water" can be produced through a variety of means, including treatment with energy delivered by an electron accelerator. Electron energy leads to the formation of highly reactive free radicals that inactivate toxic microorganisms, parasites and also decomposes the complex pollutants into less harmful and more easily treatable substance, which other means and agents cannot. Radiation treatment using electrons, causing no lingering radioactive contamination due to the low energy of the electrons.

At an industrial textile dyeing complex in Daegu, Korea, the first electron beam waste water treatment plant has been working successfully since 2006 The treatment plant handles 10 000 cubic meters of textile wastewater daily, or approximately the volume of four Olympic swimming pools.

The Daegu plant has demonstrated that "the process is safe and effective" said Bumsoo S. Han, an international expert on electron beam wastewater treatment. Han compared the performance of the existing technologies and concluded that "the electron beam technology produces the desired quality of effluent water at lower cost, without additives. It is a win for the environment and a win for the industry."

Together with its international partners, UNIDO and national institutions, the IAEA supports research and expert collaboration in the field and is pursuing wastewater treatment projects in Hungary, Iran, Morocco, Portugal, Republic of Korea, Romania, Sri Lanka, and Turkey.

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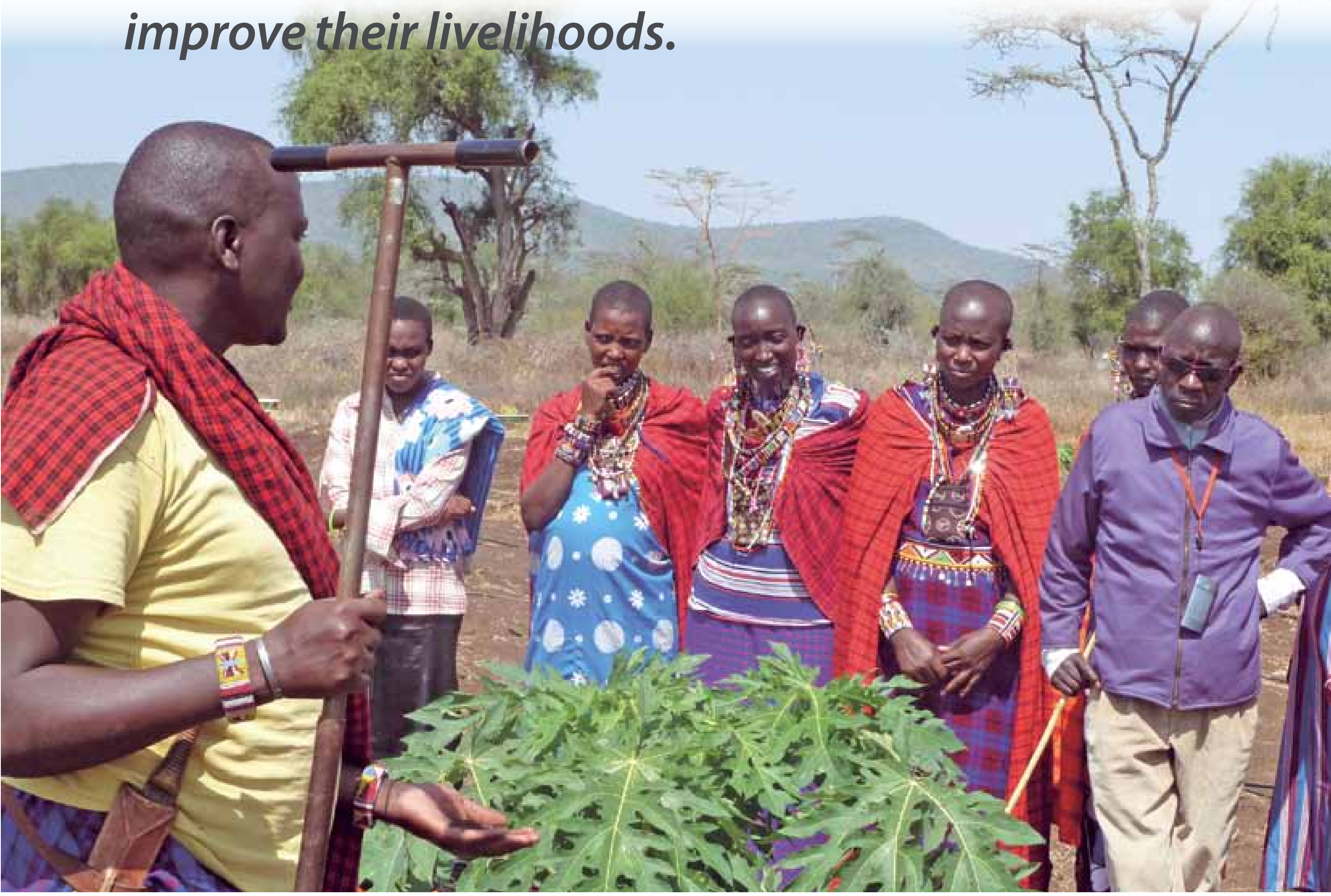
Farming when the Rains Fail

by Louise Potterton

Nuclear techniques are helping the Maasai in Kenya improve their livelihoods.



(P.Pavlicek/IAEA)

On a dusty, dry patch of land in south-east Kenya a lone Maasai man admires a thriving fruit and vegetable plot. Mangoes, papaya and spinach flourish under the searing heat of the African sun.

This is a rare sight here in Ng'atataek on the Tanzanian border, an arid region where rainfall is scarce and the little water available is usually reserved for the livestock.

But this Maasai community is fortunate. Thanks to financial support from AMREF, the African Medical and Research Foundation, they now have access to freshwater for irrigation via a borehole. By harvest time, they will have nutritious crops to eat and produce to sell at market.

This project is one of many across Africa that is operating within an IAEA Technical Cooperation project that supports the use of drip irrigation for high-value crops. With the help of nuclear technology, the system enables farmers to grow healthy crops using very little water in dry conditions.

Alex Ntasikoi, who has been trained by KARI in drip irrigation methodology, shows other members of his community how the system works.
(Photo: L. Potterton/IAEA)

It forms part of an on-going campaign, initiated by Kenya's Green Belt Movement, to improve the health and livelihoods of the Maasai people by encouraging them to move towards sustainable agriculture, while protecting the environment.

"The Maasai are by tradition pastoralists, depending on their livestock as a source of income and food," says David Mathenge from the Green Belt Movement, who oversees the project. "But times are changing. Populations are increasing and land for animals is becoming scarce. Also during the droughts livestock die, so the Maasai need to diversify."

Having access to a source of water was only part of the solution. The Maasai farmers needed to know how to use it efficiently and effectively. The Green Belt Movement approached the Kenyan Agricultural Research Institute (KARI) for assistance. Through its partnership project with the IAEA, KARI was able to help.

"We had a challenge on our hands. We needed recommendations on how best to use a small amount of water in a very dry area. We don't know how much water is needed for the plants and how much moisture there is in the soil and this is where the IAEA and its technology proved their value," adds David.

Nuclear techniques, such as the neutron probe that measures soil moisture levels, can provide the guidelines and advice the farmers need to be able to irrigate at the best times, using the right amount of water, without wastage.

"It would be very presumptuous to say that this would work without involving modern technology. Even the boreholes have low yields," David says. "If we go on irrigating using traditional methods without having a scientific basis, we might fail and could come into conflict with a community that still considers water to be more important to their livestock than to any other activity."

The Maasai site is one of nine projects that are being coordinated by the KARI under the IAEA's Technical Cooperation Programme to promote the use of small-scale drip irrigation, supported by nuclear science.

With drip irrigation, water is applied in droplets near the plant's root zone through small tubes called drip-lines. It is the most efficient form of irrigation, using up to 70 percent less water than other techniques, and can improve crop yields threefold.

This simple, low-cost set-up avoids over-watering, which can damage both the soil and the crops. Too much water can flush away vital nutrients and can increase the salinity level of the soil, which can curtail crop growth.

When plants receive too much water it can lead to runoff from the area where the crops are grown and eroded topsoil and applied fertilizers can find their way into neighbouring streams, rivers and lakes.

KARI's Irrigation Coordinator Isaya Sijali, says: "Nuclear techniques are very important and useful in agriculture. We can use the neutron probe, for example, to measure soil moisture levels and advise farmers on how much water to apply and when. These techniques can help them save water and money and get better crops while protecting the environment."

He decided to use these techniques to study the dynamics of water and nutrients at the site, since the community needed to know how to use their limited water and nutrient supplies to grow crops in a sustainable manner.

"The IAEA is directly helping these new farmers and many others will be able to benefit from this site and the findings we get from this project," says Sijali.

Experts from KARI visit the sites to explain how and why the nuclear techniques work and provide advice and guidelines based on the tests that have been carried out at their laboratories in Nairobi.

"Using isotopic techniques we can study the uptake of nitrogen, the most important element required by the plant, and advise the farmer on how to get the most benefit from the fertilizer that's been applied," Sijali adds.

In the Maasai community, Alex Ntasikoi, who has been trained by KARI in drip irrigation methodology, shows other members of his community how the system works.

"We've really seen the benefits of drip irrigation," he says. "The system is cheap and requires little water, which is very important in our region because we have so little of it. Also, the plants get less disease because the water goes into the roots and not on the leaves," Ntasikoi says.

But the real beneficiaries of this project are the Maasai women. The men can be away for up to a year in pursuit of grazing land for their livestock, while the women and children remain in the community.

"Drip irrigation is a new technology for us and since it's been introduced we can plant our own vegetables and don't have to depend on livestock alone," says Mary Kashu. "We can improve our children's nutrition and raise some income. We can use the money to pay school fees and to maintain the pump to get more water from the borehole."

The IAEA is currently implementing the drip irrigation project in 19 countries in Africa. Lee Heng, a water specialist who manages the project, says: "We hope that this project will empower the farmers to farm in an efficient, productive and sustainable manner."

She adds that agriculture is responsible for around 70% of freshwater use and for most of the world's groundwater depletion. However, on average, only 37% of this water is used efficiently, due to inappropriate irrigation technology and farming practices.

"As water becomes more and more scarce and growing populations demand more food, it is of paramount importance that we manage agricultural water better to grow more crops for every drop of water we use in both rain-fed and irrigated agriculture," says Lee.

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Seeing Through Soil

by Peter Kaiser

Nuclear technology helps farmers make the most of water

Irrigation consumes seven of every ten litres of fresh water used daily around the world. As global population rises, so too does the demand for food, which is satisfied by expanding cultivation and increasing irrigation. If irrigation efficiency can be boosted, much can be done to reduce farming's thirst for fresh water, and help preserve this irreplaceable resource.

(P.Pavlicek/IAEA)

One of the nuclear technologies employed in tackling water scarcity and saving water in agriculture is a "soil moisture probe", or "neutron probe", which is used to measure how much water is present in the soil surrounding the probe. Measurement across a farm plot provides the farmer invaluable insights into an otherwise invisible phenomenon: how much of the irrigation or rainwater is held in the soil and how much of that water is accessible and used by plants.

In the hands of a trained and licensed operator, a probe can literally see through soil to detect the faintest traces of water. The device is so sensitive it can even calculate how much water a plant consumes.

By flicking a switch, the operator can trigger a specially shielded, tiny radioactive source that emits a thin stream of neutrons. They travel at great speed through the soil. The passage of those neutrons that struck hydrogen atoms in water molecules is dramatically slowed. After the neutrons collide with other particles, they are reflected back towards the probe, which measures the speed of the returning neutrons. Water's braking effect on the neutrons is registered by a detector within the probe. Thus, the amount of returning, slower-moving neutrons counted by the detector indicates the soil's hydrogen content. The probe translates this data into an exact soil-water content measurement, which is expressed in millimetres of water. That data is exactly what the farmer needs to immediately plan irrigation and water storage strategies that make the most of water for irrigation.

The probe itself does not cause any radioactive contamination, nor are any radioactive traces left in the soil.

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If I Had




Farmers in Kimutwa, Machakos county, Kenya are "praying" that it will rain. It's been declared a failed season for agriculture and rainfall is becoming more infrequent.

1 Cecilia and Philip Munguti run a small farm in Kimutwa. "It's a disaster, my crops have dried up because there's not enough rain. We could have eaten them or sold them. If I could get water from a borehole, I could irrigate; it would not be like this," says Cecilia.

2 Around 80% of Kenyan farmland is classified as arid and semi-arid with low and erratic rainfall. But with no water for irrigation, from wells or boreholes, most farmers rely on the rains.

3 The Munguti family used to have water that came directly from the hills into their village tank, but now the tank is empty.

4 Dried up rivers, ponds and empty water tanks are a common site in Kenya. Whether for farming or domestic use, there's simply not enough water. One farmer says: "We're in trouble, facing starvation."

Water...

by Louise Potterton

An IAEA project is showing these farmers, who depend on rain-fed agriculture, how to grow crops in the driest of seasons using isotope-based water, soil and nutrient management practices.

5 The Munguti family uses this rain-filled pond, the Kwa-Aka dam, for water for washing, cooking and drinking. The water is heavily polluted with animal waste and from soil erosion.

6 Cecilia and her family rely on this water, there's no alternative: "The water is dirty. We have to boil it before we use it. Some animals even die when they drink it. There are worms and liver flukes in there," she says.

7 Philip Munguti says: "The water in the pond is dangerous, animals come here too to drink and they pollute it. It's used by nearly 2,000 people. People walk far to get here, but when the water is gone, we will need to go even further to get it."

8 People walk for up to 10 kilometres to reach the Kwa-Aka dam. One local woman explains: "We need to get our water for domestic use from here. We use our backs to carry it. It's dirty. It makes people ill. There are people in the local hospital with typhoid."

9 The IAEA is working with the Kenya Agricultural Research Institute (KARI) to help farmers like the ones in Machakos, grow healthy crops despite the lack of rain with the support of nuclear and isotopic techniques.

10 KARI soil scientist Kizito Kwena, who was trained by the IAEA in Vienna, Austria, is using nuclear science to conduct research on plants that thrive with little water, retain moisture and improve soil fertility. He shares that knowledge with local farmers.

11 Some farmers' crops have withered in the drought. The little water available to this community from the Kwa-Aka pond is needed for domestic use and is insufficient for irrigation. One farmer says: "Our season was so bad, there's not enough food."

12 At this IAEA experimental site the crops are thriving despite the lack of rainfall. Kizito Kwena says: "We have a variety of crops under different cropping systems and we need to figure out the most water efficient ones and this is where nuclear techniques play an important role."

13 The IAEA project is also supporting the cultivation of the legume "pigeon pea" in Kenya. Nuclear-based research has shown that the plant is not only drought-tolerant but also improves the soil's capacity to retain water. Furthermore, it acts as a natural fertilizer for present and future crops.

14 For some farmers in Machakos, the IAEA project is showing benefits. Many crops have indeed died, but the pigeon pea and cassava are surviving, thanks to good soil and water management practices, supported by nuclear science. "I've used pigeon pea as a fertilizer and it's working really well," says Cecilia.

Since these photos were taken in June 2011 the Kwa-Aka dam has dried up.

Photos: Louise Potterton and Petr Pavlicek/Division of Public Information • **Text:** Louise Potterton by Louise Potterton

No Rain, No Food

How Nuclear Techniques can Support Agriculture in Dry Conditions

In many parts of the world, either too much or too little rain falls, often at the wrong time, leading to water scarcity, droughts and crop failure.
(Photo: P. Pavlicek/IAEA)

Access to sufficient water supplies is essential for successful and sustainable farming. Without water, crops die, farmers lose their income and people go hungry.

There are two types of cropping systems namely irrigated and rain-fed.

Agriculture that depends upon rainwater represents about 80 % of the total area under cultivation and produces the majority, or about 60%, of global food.

In many parts of the world, either too much or too little rain falls, often at the wrong time, leading to water scarcity, droughts and crop failure.

The IAEA's Soil and Water Management and Crop Nutrition section is using nuclear and nuclear-related techniques to help farmers in the developing world to conserve water and cope better under dry conditions.

Louise Potterton spoke to IAEA soil and water expert, Karuppan Sakadevan.

What are the major challenges to rain-fed agriculture and how is it different from irrigated agriculture?

Rain-fed agriculture is a low-input system. Depending on total annual rainfall and its distribution as well as the type of soils, productivity can vary greatly from moderate to low.

Agriculture that depends on rain is more risky with the possibility of crop failures in drier areas due to erratic and unpredictable rains. Rain-fed agriculture is generally more successful on soils that can store a lot of rainfall (i.e. loamy and clayey soils).

On the other hand, irrigated agriculture can be highly productive with low risk but at a high input cost (i.e. irrigation equipment, energy)

How can the IAEA help farmers who practice rain-fed agriculture conserve and manage water?

The IAEA through its Research and Technical Cooperation Programmes has implemented 30 water conservation projects in rain-fed agriculture in IAEA Member States in Asia, Africa and Latin America. These projects focus on practises such as minimum tillage, crop residue retention and crop rotation.

On average, 65% of rainwater is lost and not available to crops in rain-fed agriculture. Farmers need to capture and store water so they can use it during the dry period.

Conservation or minimum tillage is a farming practice in which crops are grown with minimum soil disturbance. It reduces the breakdown of soil organic matter and therefore increases the water holding capacity of the soil. This tillage practice along with crop residue incorporation into the soil reduces water loss through evaporation and the impact of rainfall on soil erosion.

Another example of addressing water scarcity is water harvesting. This involves collecting and storing runoff water in natural or man-made farm ponds and wetlands that can be used for supplementary irrigation or drinking water for livestock. We also run programmes that support the selection of drought and salinity-tolerant crops, such as rice and wheat.

What are the nuclear techniques involved?

In order to save every drop of water, we need to know where the water goes. Isotopic techniques can help to trace the movement of water between soil, plant and atmosphere.

In water harvesting, the oxygen isotope (oxygen-18) is used to identify water sources such as surface runoff and seepage flow entering into farm ponds and wetlands. This will allow farmers to design the size and identify best locations for developing these farm ponds and wetlands.

Since oxygen is a major element of water, the use of oxygen-18 isotope can help to separate the water loss from soil by evaporation and plant uptake. This helps in developing management practices such as tillage, residue retention, plant density and crop rotation for reducing soil evaporation losses.

A crop's ability to capture every drop of water depends on its health. That is why it is important to know whether a nutrient such as nitrogen, a major building block of crop growth, is sufficiently available. Nitrogen-15, a stable isotope of nitrogen can be used to measure the efficient use of applied fertilizer nitrogen to crops under different management practices and thus determine the efficient use of water by crops.

Since carbon is another major component in plant growth, the amount of carbon stable isotopes in light (carbon-12) and heavy (carbon-13) fractions can help us to identify crops that are tolerant to drought.

We also use the neutron probe, an instrument used to measure the amount of water stored in the soil and to assess the effect of different management practices such as tillage and crop residue retention on soil moisture holding capacity.

Can you give me more details about water harvesting?

Water harvesting and storage is gaining increasing importance in arid and semi-arid regions throughout the world as water becomes increasingly scarce, due to changing climatic conditions, erratic weather events or the unsustainable use of existing water. With this technique, rain water is captured, usually in a pond on a farm.

Water harvesting acts as a buffer against drought, providing water for livestock and a limited capacity for irrigation and fire protection.

Can you give me an example of an IAEA project where these practices are working?

IAEA has implemented water harvesting technology in China, Estonia, Iran, Lesotho, Nigeria, Romania, Tunisia and Uganda to increase the productivity of rice, wheat and vegetable crops through a network of coordinated research projects.

Through both Technical Cooperation projects and coordinated research projects, conservation agriculture practices have been implemented in Argentina, Brazil, Chile, India, Kenya, Morocco, Mexico, Niger, Pakistan, Turkey, Uganda and Uzbekistan to increase water availability for crops during the growing period. And our projects have achieved good results. In Niger, cowpea production increased nine-fold by using crop rotation with millet and crop residue retention. In Pakistan, crop residue retention and crop rotation increased wheat yield by 18%.

What about extreme drought situations — how can nuclear techniques help here?

Extreme drought situations arise when a region receives below average or no rain for months or years. During prolonged droughts, losses in crop and livestock production can reach 50% or more. The projects we operate that support water conservation and harvesting are useful in these conditions, since water stored in farm ponds and wetlands can be helpful for irrigating crops for one or two growing seasons.

Also we have projects that use nuclear-based research to support the cultivation of drought-tolerant crops. For example, pigeon pea and cowpea are tolerant to drought as they develop deep roots and extract water from depths up to two meters below the soil surface.

The IAEA also develops soil management techniques. Does soil play an important role in water management?

It certainly does. Soil is different all over the world. Certain crops thrive better in certain soils and different soils can hold varying amounts of water.

The physical properties of the soil, such as particle sizes and the proportions of clay, silt and sand, its chemical properties and its mineralogy can determine how much water the soil holds, for how long and to what depth.

The physical properties of the soil, such as particle sizes and the proportions of clay, silt and sand, its chemical properties and its mineralogy can determine how much water the soil holds, for how long and to what depth.

(Photo: P. Pavlicek/IAEA)

The amount of water that is retained within the root zone for crop use also depends on the activity of soil organisms and earthworms that influence water runoff along the soil surface or water movement and retention within the soil. So technologies that help to improve the physical, chemical, and biological properties of soils are vital to improving agricultural water management.

Which nuclear techniques are used to improve soil fertility?

Stable isotopes of nitrogen and carbon are used. These techniques are not used directly to improve soil fertility, but help us to identify on-farm management factors that influence the extent of the movement of nutrient of added organic matter between soil and plant across agricultural landscapes.

This information is useful to provide advice on the best soil and nutrient management practices that enhances soil fertility and reduce soil degradation.

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by Rodolfo Quevenco

SUSTAINABLE MANAGEMENT OF COASTAL WATERS

A profile of the history and levels of coastal pollution in the Caribbean emerges

Five years is but an instant in the course of centuries recorded by the science of ocean sediment core sampling. But for the marine scientists gathered in Monaco in Spring 2011, the last five years yielded a treasure trove of data on the study and understanding of coastal pollution in the Caribbean.

The scientists represented countries sharing the coastal resources of the Caribbean Sea -- Colombia, Costa Rica, Cuba, Dominican Republic, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, and Venezuela. Joined by experts from the IAEA, Spain and its Environment Laboratory in Monaco, they met in a special session on the Caribbean during the International Symposium on Isotopes, Marine Ecosystems and Climate Change.

The session aimed to assess results of a regional project using nuclear techniques to measure the paths of coastal pollution in the participating Caribbean countries. First launched in 2007 under an IAEA Technical Cooperation project (RLA/7012), the project involved taking sediment core samples in all 12 countries, and analyzing these samples to determine the trend and history of pollution from heavy metals and organic contents for the last 100 years to support decision makers' appropriate environmental management decisions. Equipment and training were provided under the project to strengthen the analytical capabilities of participating countries' scientific institutions.

To date, about 6000 data points have been generated from the analysis of the sediment cores submitted by the participating countries. This information, including the trend of mercury pollution analyzed in the sediments, is the first-ever comprehensive results reported in the area.

There are similarities across the region and common pollution trends. For example:

◆ The coastal areas in the Caribbean are mainly used for tourism, fishing, industry and commerce, seaports, and as shelter for marine biodiversity;

◆ Coastal pollution has been steadily rising and results mostly from domestic sewage discharges, industrial waste dumping, residue from oil and other fossil fuels, shipping and port activities, hurricanes and other natural, agricultural runoffs, and deforestation and soil erosion;

◆ The most common types of coastal pollution result from high concentrations of heavy metals (lead, mercury), inorganic elements (cobalt, chromium, zinc, nickel), and organic pollutants (pesticides and polynuclear aromatic hydrocarbons).

Colombia

The Bay of Cartagena is one of Colombia's major waterways. It is a hub for tourism, for fishing and for industry. It also has one of the largest ports in the Caribbean and a manufacturing base for hundreds of small and medium factories.

Pollution in the Bay of Cartagena can be attributed to domestic sewage discharges; industrial dumping; leachate landfills; and sediments from the Canal del Dique.

Built over 300 years ago to connect Magdalena River to the Bay of Cartagena and the islands of Rosario and Barbacoa, Canal del Dique is considered to be the major source of sediment discharge for the bay. Its impact has been catastrophic for the bay's ecosystems, leading to the existing coral reefs' destruction, as well as of all sea grass. Dating tests indicate an increase in the sedimentation rate in recent years, due most likely to changing land use and climatic events affecting the canal watershed.

Across the Caribbean, pollution by heavy metals, including mercury, is causing increasing concern about its effects on tourism, clean beaches, and fishing. The presence of mercury in fish can be a health issue. This fisherman in Nicaragua relies upon clean water to catch fish that are safe for him and his family to eat.

(Photo: D.Sacchetti/IAEA)

Mercury pollution is also evident in Cartagena Bay, according to the analysis presented, with high concentrations detected in the deeper sediment layers.

Efforts are invested in ensuring the canal's navigability, but not the sustainability of the ecosystem. Dredging can further mobilize mercury present in sediments, thus emphasizing the need and importance of heavy metal pollution control in Cartagena Bay.

Cuba

The Bay of Havana is Cuba's major waterway and gateway to its capital city. The coastline is densely populated and includes a large number of industries that dump their sewage into the water. An oil refinery and the sewage system built as part of industrialization and urbanization have contributed to oil and organic pollution in the bay.

Sedimentation rates show an increase from 1890 to 1980 with peaks attributed to severe weather events that have hit the area. From 1990 there has been a reduction of sediment accumulation rates, coinciding with efforts to reduce socio-economic activities and implement sound pollution reduction measures.

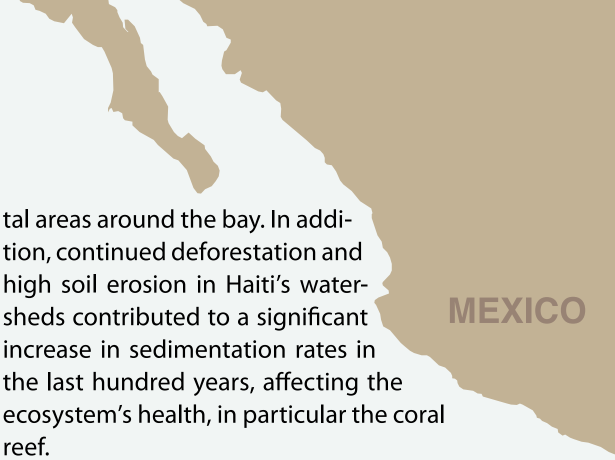
Overall, measurements continue to indicate pollution levels are higher than values prior to values from the 19th century but that management measures implemented in the bay since 1990 have helped restore the natural flow of sediments in the marine ecosystem.

Data collected have made it possible to understand the evolution and current state of pollution, and demonstrate the impact of rehabilitation programs to restore the environmental quality of the ecosystem.

Dominican Republic

Huge volumes of agricultural pollutants and industrial and municipal waste make their way into Rio Haina from industrial areas in the basin and from the city of Santo Domingo. The country conducted its first studies to assess the extent of the contamination in the mid-90's. From 1995 onwards, a recovery program was implemented to reduce the effects of pollution. Some improvements have already been reported.

Analysis of the sedimentation at Rio Haina indicate peaks during periods of extreme weather events, for example, strong hurricanes that struck the area in 1940, 1945, 1979 and, again, in 1998.



While recorded levels of organic and inorganic pollutants are low, there is an increased trend in the presence of lead, arsenic and other organic pollutants in the area.

Pesticide pollution – from DDTs – fluctuated in correlation with their use in farming activities, decreasing from the 1980s onwards as use of these pesticides were gradually discouraged.

Guatemala

Amatique Bay is a semi-enclosed body of water along the eastern coast of Guatemala hosting a complex ecosystem of coastal lagoons, swamps, marshes, river systems and channels that connect protected waters and the adjacent continental shelf. Fishing, tourism, shipping and marine conservation are among the main activities in the bay. Coastal and marine tourism alone accounts for 2% of Guatemala's gross domestic product; tourist visits have steadily increased through the years.

These activities are believed to contribute to contamination, in terms of leachate from solid waste; industrial effluent discharges; agrochemical runoffs and domestic sewage. However, it is soil erosion and deforestation that has been identified as the main environmental problem in the Amatique Bay.

According to a 2006 environmental profile of Guatemala, the country lost 11% of its forest area in the last 10 years, resulting in increased sedimentation rates in the bay area.

The continuous growth in sedimentation rates increases the vulnerability of fragile reef systems in the Atlantic region of Guatemala, and could directly impact the fisheries of the region.

Increased traces of heavy metal pollution have also been detected, but this has been attributed more to increased sedimentation rather than the level of industrial activity.

Haiti

Port-au-Prince Bay acts as a natural harbour for Haiti's like-named capital city. It hosts much of the country's industrial activities, such as loading docks, fuel storage, food processing, cement manufacturing, and metal processing, which constitute the major sources of pollution for coastal areas around the bay. In addition, continued deforestation and high soil erosion in Haiti's watersheds contributed to a significant increase in sedimentation rates in the last hundred years, affecting the ecosystem's health, in particular the coral reef.

Although industrial activity in Port-au-Prince Bay is limited, the generation of solid and liquid waste dumped into the bay — estimated at 1500 tonnes per day — resulted in a steady increase of heavy metals in the water, particularly lead and mercury. This represents a potential danger to public health from the consumption of marine organisms.

Information and data gathered so far on the evolution and state of pollution in the bay is expected to serve as baseline for evaluating policies and coastal management programmes to be established.

Honduras

The bay in the coastal city of Puerto Cortes in Honduras is the site for its fuel and mineral storage industries, fertilizer plants, and textile manufacturing. Central America's largest port – a hub for cargo vessels and luxury cruise ships – is also located along the bay. These activities, coupled with rapid population growth, constitute the main sources of pollution in the bay area.

At the same time, the high rates of erosion in the region, prolonged flooding of the coastal zone, and uncontrolled disposal of urban waste have contributed to increased sedimentation in the coastal areas. Hurricanes' seasonal passage aggravates the situation, resulting in increased pollution load and heavy metals discharge into the marine environment. The rate of sedimentation has tripled in Puerto Cortes in the last 50 years, and is expected to double its current rate in the next 20 years if left unchecked.

At the current rate of sedimentation, Honduras expects that the frequency and cost of dredging the harbour area may increase in the near future. Urgent measures may also have to be taken along the upper basins of the rivers Ulua and Chameleon to control soil erosion.

Jamaica

Kingston Harbour provides fishing, port and airport facilities for Jamaica. It is the site for thousands of industrial and commercial enterprises, as well as home for nearly one million people. However, the water quality has badly degraded, and the surrounding area has deteriorated, thus reducing its environmental use and touristic attractiveness. Pollution and alien species brought by shipping additionally threaten its rich biodiversity.

Environmental studies at Kingston Harbour highlight two major problem areas: severe eutrophication (increased presence of chemical nutrients in the water) and continuing deterioration of the water quality from untreated industrial wastewater, disposal of agrochemicals and sewage, and an increased sedimentation rate in Hunts Bay caused by the Portmore Causeway, a bridge connecting Portsmore to Kingston.

Higher levels of polynuclear aromatic hydrocarbons have also been detected since the 1980s.

At the same time, high levels of metals were found in some sediments. The experts advise that the government should take this into account in coastal management efforts, and should also consider studying the uptake of metals by marine biota.

Mexico

The Coatzacoalcos River is the third largest river in Mexico. The industrial corridor built along its banks is home to about 65 petrochemical plants including the Lazaro Cardenas refinery, the oldest in the country. Waste water from industrial processes and expanding human settlements have dramatically altered the environmental profile of this important river basin.

Dating measurements using lead-210 showed that an increased rate in sedimentation and associated pollutants began to appear with the rapid urban growth and industrial expansion between 1970 and 1990. The increase in average sediment accumulation rates is most likely a result of soil erosion caused by changes in land use to support industrial and urban development in this area.

Increased oil pollution is also evident in the river estuary. Concentrations of organic pollutants in core sediments point to the burning of fossil fuels as a probable cause. From 1980 onwards, heavy metal concentrations in the area have reached levels that could pose a risk to marine

Juan Pablo Parra of the Instituto de Investigaciones Marinas y Costeras (INVEMAR) laboratory in Colombia, recovers sediment from the seabed to check it for pollutants. After extracting a sample from the ocean floor, Parra will use nuclear techniques to identify contaminants and reconstruct the pollution sources.

Parra received training in using nuclear techniques to analyse sediment through a program supported by the IAEA's Technical Cooperation Programme.

(Photo: D.Sacchetti/IAEA)

biota. The experts recommend a program of periodic checks, including measures to control the amount of urban and industrial going into Coatzacoalcos river and its tributaries.

Nicaragua

The Bluefield Lagoon in the south Atlantic autonomous region of Nicaragua is an ecological haven for a variety of marine life and ecosystems. It provides a natural habitat for fish, crustaceans and marine species of great commercial interest. However, rapid population growth in settlements around the lagoon, and increased activities in fishing, forestry, and agriculture are threatening the balance of this delicate ecosystem.

The lagoon is also the main tributary of the Escondido river, which carries an estimated 11.6 billion cubic metres of sediment and river flow each year. Moreover, the devastation from Hurricane Joan in 1988 almost completely destroyed the basin and added significantly to sediment build-up.

Analysis of lead-210 dating and other environmental indicators have helped Nicaragua evaluate changes in the sedimentary process and identify possible causes. They also indicate trends of increased level of inorganic pollution in the last 100 years.

Nicaragua will be using knowledge gained from these analyses to replicate the study in other coastal ecosystems in Nicaragua with similar conditions, and even extend the study to inland water bodies.

Panama

A major economic activity in Almirante Bay in the province of Bocas del Toro, Panama, is the processing of bananas for export. Bananas have been grown in the area for over 100 years; it is an agricultural activity noted for its high dependence on agricultural chemicals and fertilizers and for increased cargo ship traffic to the local seaports.

This major industry thus accounts for the bay's increased pollution by organic chemicals and hydrocarbons. Another source of contamination emanates from the settlements along the Bay of Almirante. The absence of adequate treatment plants means waste-water, solid waste and sewage are deposited untreated directly into the bay or nearby rivers. In the last decade, the increasing the number of passengers who travel, for tourism, to Colon Island via water taxis, has exacerbated this situation.

These factors, combined with the bay's topography that inhibits the water's active exchange with the open sea, and the deforestation of the mangrove forest, have resulted in increased levels of environmental degradation of the marina in the Bay of Almirante.

Each of these country reports stress that data on the trends in heavy metal and organic pollution gathered for the last 100 years will be a useful tool for decision makers in crafting strategies for sustainable coastal management.

The Next Steps

The project on the sustainable management of the Caribbean Sea is scheduled for full completion in 2012.

Until then, follow-up training on the use of lead -210 for dating sediments and a review meeting for all counterparts are still foreseen. More important are strategies to make these reports available — in full and concise form— to as wide an audience as possible. The results will be presented at an inter-governmental meeting of the United Nations Environment Programme in the Caribbean for higher-level dissemination.

Strategies to further support Caribbean countries in developing and sustaining their individual capabilities for environmental monitoring and management should thereafter be developed to lend meaning to these valuable scientific results.

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Staff from the Department of Technical Cooperation and Nuclear Science and Nuclear Applications contributed to this article.

Counterpart Institutes

The following national institutes participated in the regional project for sustainable coastal management of the Caribbean:

❖ Instituto de Investigaciones Marinas y Costeras (INVEMAR), Colombia (Institute of Marine and Coastal Research)

❖ Universidad de Costa Rica (UCR), Costa Rica (University of Costa Rica)

❖ Instituto Costarricense de Acueductos y Alcantarillados, Costa Rica (Costa Rica Institute of Aqueducts and Sewage Systems)

❖ Japdeva, Costa Rica

❖ Ministerio de Ciencia, Tecnología y Medio Ambiente, Cuba (Ministry of Science, Technology and Environment)

❖ Universidad Autónoma de Santo Domingo, República Dominicana (Autonomous University of Santo Domingo)

❖ Ministerio de Energía y Minas (MEM), Guatemala (Ministry of Energy and Mines)

❖ Empresa Portuaria Quetzal, Guatemala (Quetzal Port Enterprise)

❖ Ministère de l'environnement, Haïti (Ministry of the environment)

❖ Secretaria de Recursos Naturales y Ambiente (SERNA), Honduras (Secretary of Natural Resources and Environment)

❖ National Environment and Planning Agency, Jamaica

❖ Universidad Nacional Autónoma de México, México (National Autonomous University of Mexico)

❖ Universidad Nacional Autónoma de Nicaragua, Nicaragua (National Autonomous University of Nicaragua)

❖ Autoridad de Recursos Acuáticos de Panamá, Panamá (Authority for Aquatic Resources of Panama)

❖ Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Spain (Centre for Energy, Environment and Technology Research)

❖ Universidad del Oriente, Venezuela (University of the Orient)

DETECTING A

A sudden onset of harmful algal blooms (HABs) can poison fish, shellfish and other marine life, and pose a major threat to peopleís health and fishermen's livelihoods.
(Photo: F. Boisson/IAEA)

They are the seas' silent killers, toxin-laden patches of algae that amass along coastal shores and wreck havoc on marine eco-systems. They appear with no warning and out-breaks have become more frequent. Virtually every coastal country in the world has suffered from their effects.

These are harmful algal blooms (HABs), more commonly known as 'red tides' because their ominous presence is sometimes characterized by a massive red patch of water encroaching the shorelines. Often outbreaks are invisible and thus pose an even greater threat. HABs occur when colonies of algae—simple ocean plants that live in the sea—grow out of control and produce tox-ins that can poison fish, shellfish and other marine life, and pose a major threat to people's health and fishermen's livelihoods.

Not all algal blooms are harmful. In fact, most of them sustain marine life, providing a vital source of nutrients for a host of sea creatures. Certain algal species produce poisons called saxitoxins. When conditions are ideal – i.e., higher nutrients in water through coastal upwelling or agricultural runoffs - these algae can "bloom" and overpopu-late, inevitably resulting in the release of massive amounts of toxin that kill fish and can accumulate in clams, mussels and shellfish, making them dan-gerous to eat. Paralytic Shellfish Poisoning (PSP), characterized by death through paralysis of the respiratory system, is one of the most common health threats from eating contaminated shell-fish.

Despite its 'red' moniker, many outbreaks of HABs often do not discolour the water, or may have other colours like green or yellow. In fact, most blooms are difficult to detect with the naked eye. Undetected, the risk of spoiled fish harvests and/or contaminated sea products entering the human food chain increases many times over.

The global impact that HABs can have on human health, economies and the ecosystem, makes it one of the most serious, naturally occurring coastal problems in the world. As outbreaks of these poisonous blooms of algae become wide-spread and more frequent, the IAEA is stepping up efforts to help countries understand the phe-nomenon and use more reliable methods for early detection and monitoring so as to limit HABs' adverse effects on coastal communities everywhere.

Detection as the Best Form of Prevention

Early detection is key in HABs control. For dec-ades, the conventional method to test for impend-ing red tide events was through mouse bioassay.

KILLER TOXIN

by Rodolfo Quevenco

Scientists would inject toxin extracts from suspect algae or shellfish samples into a laboratory mouse and measure how long it would take for the mouse to die. The mouse bioassay method is considered to have a low sensitivity, and is not able to precisely pinpoint levels of toxicity.

A nuclear-based technique using receptor binding assay (RBA) is benign, quicker and much more precise. RBA works by mixing a shellfish sample with a 'marker' — in most cases, tritium-labeled saxitoxin — then exposing the mixture to a tissue sample. If the shellfish is contaminated, the poisons compete with each other to "bind" to the nerve cells of the tissue, with the radioactive toxin being displaced or "bumped off' its receptors by poison already present in the shellfish. By measuring the amounts or radioactivity left, scientists can then pinpoint exactly what the levels of toxic concentrations are.

RBA is thus a far more sensitive and precise measuring method, and the IAEA has long been spearheading efforts to widen its use among as many countries as possible. To this end, it has entered into partnership agreements with international organizations involved with HABS; it actively facilitates international collaboration on the use and advancement of RBA, and supports several regional and national projects.

Currently 23 IAEA Member States have active technical cooperation projects dealing with the monitoring and early warning of seafood toxicity using the RBA method. Several successful applications of RBA for HABs have been reported and documented in Chile, El Salvador, Namibia, and the Philippines, to name a few.

RBA Research and Deployment

Leading the IAEA's efforts on HABs is its Environment Laboratories in Monaco (NAEL). For years, the laboratory has been at the forefront of promoting the use of RBA for early detection and monitoring of HABs occurrences in Member States.

Philippine Nuclear Research Institute Director, Alumanda de la Rosa, says completion of major modifications to the receptor binding assay technique would enable the technology to be brought to the field.
(Photo: D. Calma/IAEA)

Florence Boisson, a scientific consultant of the Principality of Monaco working at NAEL, believes the IAEA has a clear leadership role in delivering the benefits of the RBA to its Member States.

To further understand the paths used by the HABs toxin to enter seafoods, NAEL Monaco works with its Collaborating Centre — the Philippine Nuclear Research Institute (PNRI) — to apply RBA in field studies at selected aquaculture areas in the country. PNRI's pioneering work in RBA since the late 1990s, and the country's rich aquatic resources, makes it an ideal partner for research and development work. Experts are giving special attention to measuring the transfer and elimination of the biotoxin which causes PSP, and tracing the transfer of the toxin from the shellfish all the way up the human food chain.

With technical support from NAEL Monaco, the Philippines is also extending R&D work to modify the procedure and instrumentation — for example using iodine-125 instead of tritium and a gamma counter instead of liquid scintillation — which would allow the procedure to be performed in the field or in small laboratories in the coast. Analytic results would be quicker, and alerts of impending red tide events can be announced at a shorter notice.

PNRI, whose status as IAEA Collaborating Centre on HABs was renewed in July 2011, hopes to fin-

A fisherman in Sorsogon Bay in the Philippines sets out at dawn for the early morning catch.

(Photo: F.Boisson/IAEA)

ish major RBA modifications this year. When completed the technology will then be shared with other IAEA Member States through an IAEA technical cooperation project.

"It is an honour for the Philippines that our peers recognize the work that we have done in this area", says PNRI Director Alumanda de la Rosa. " We are also glad that our R&D strategies have become the model that other regions can use in studying their HABs problem."

Horizons of International Cooperation

In early 2011, IAEA and the US National Oceanic and Atmospheric Administration (NOAA) signed a practical arrangement formalizing their collaboration to provide technical assistance in the management of the impacts of HABs.

This announcement followed in the heels of a major meeting of an international scientific advisory committee on harmful algal blooms organized by the IAEA in March 2010. Held in Charleston, South Carolina, the meeting brought together international experts known for their expertise in the use of receptor binding assay for HABs.

The meeting reviewed reports on existing applications of RBA for HABs; addressed issues of supply for radio-labeled reagent toxins; defined strategies for further development; and plotted the course for strengthened international collaboration among organizations involved with HABs. It was held as part of an IAEA inter-regional project (INT/7/017) to provide coordinated support for using RBA to address impacts of harmful algal toxins in seafoods.

One overall project aim is to build a support structure to allow countries to develop and implement strategies and programmes on HABs. Another is to upgrade regional capabilities in receptor binding assay through training and technology transfer.

As a part of the tripartite agreement between the IAEA, UNEP and UNESCO's International Oceanographic Commission (IOC), signed on 25 February 2011, a long-term collaboration began with the IOC to build countries' capacity to monitor HABs. This collaboration has already resulted in regional initiatives in Africa and Latin America aimed at strengthening these regions' capacity to monitor outbreaks of harmful algal blooms.

"One overall project aim is to build a support structure to allow countries to develop and implement strategies and programmes on HABs. Another is to upgrade regional capabilities in receptor binding assay through training and technology transfer", says Boisson.

A direct offshoot of this international coordination is a *Manual of Methods for Harmful Algal Toxin Detection Using RBA*, due for issue in late 2011. A joint endeavor by the IAEA and NOAA, the manual will serve as a useful guide for developing countries wanting to use RBA for HABs. It is another step forward in the growing acceptance – and use – of RBA to help detect and forecast the location of harmful algal blooms.

Controlling the toxic menace from the sea will continue to be an elusive goal for years to come. Continued research in technologies like RBA are helping to bridge the gap in understanding the phenomenon of the 'red tide; and forewarning of its coming.

With health and livelihood in the balance, these are potent tools for countries that need them the most.

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Protection from a Toxic Menace

by Sasha Henriques

IAEA helps El Salvador handle the threat from Harmful Algal Blooms

The potentially deadly toxins released by Harmful Algal Blooms (HABs) threaten El Salvador's shellfish harvest and pose a grave health risk. Through several of the IAEA's Technical Cooperation projects, scientists at the Laboratory of Marine Toxins of the University of El Salvador (LABTOX-UES) have received support from the IAEA's Technical Cooperation Programme in setting up a permanent monitoring system that provides early warning of toxins in microalgae and seafood products.

The IAEA equipped the laboratory and provided training on specialized detection equipment that is used to monitor HABs. This is a unique capability that no other laboratory in the region has yet developed.

The government relies on the facility to detect toxicity in HABs for its early warning system, which is used to alert fisherman and locals as soon as there is a dangerous concentration of toxins in the water.

This system depends on a network of monitoring stations located in fishing parks. Samples from the monitoring station are brought to the facility for analysis. The new toxin detection methods are faster and allow scientists to analyse more samples, and thus provide an early warning of a HAB-induced spread of toxins.

The concept was proven when an early warning of a "red tide" was issued in 2010. LABTOX-UES publishes its analyses online (http://toxinasmarinas.cimat.ues.edu.sv) to support early warnings of algal outbreaks and help reduce the health threat posed by this natural killer.

What is the IAEA doing globally?

The IAEA's Department of Technical Cooperation, together with international and national organisations around the world, works with national marine institutes and governments to tackle the issue.

HAB events have become a common problem both in developed and developing countries, affecting public health and the shellfish and fish farming industry.

(Photos: Nancy Falcon Castro/ UNIDO)

The IAEA equipped the Laboratory of Marine Toxins of the University of El Salvador and provided training on specialized detection equipment used to monitor HABs. (Photos: Nancy Falcon Castro/ UNIDO)

In addition to its work in El Salvador, the IAEA works with the Philippine Nuclear Research Institute, which is the only IAEA collaborating centre on HABs in the world. The Institute undertakes research with the IAEA Environment Laboratories in Monaco to track the impact and fate of biotoxins in the marine food-chain.

Through the Technical Cooperation programme, 14 marine laboratories were established in Africa, Asia and in Central and Latin America. Through an on-going project in the Caribbean and Latin America, the IAEA will be establishing three more laboratories by 2013 and will develop the capabilities of eight other countries to detect HABs.

Also, a new regional project in Asia will enhance the capacity to monitor the impact of toxic algae by addressing ciguatera (a disease contracted when one eats fish contaminated by toxins).

These facilities are prime examples of the benefits of cooperation between the IAEA and Member States to protect national food security, public health and the economy.

They contribute to the sustainable management of fishery products and the coastal economy, increase food security and are a resource for faculty, students and the Government: all benefits that will last long into the future.

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The IAEA's Technical Cooperation Department's Communication staff also contributed to this article.

by Peter Kaiser

An Ocean of Knowledge

On 10 March 1961, the IAEA concluded with the Principality of Monaco and the Oceanographic Institute, then directed by Jacques Cousteau, their first agreement on a research project on the effects of radioactivity in the sea. Fifty years later, that cooperation expanded significantly through collaboration with international and regional organizations, as well as national laboratories. The Laboratories that grew from this initial agreement comprise the only marine laboratory in the United Nations system that undertakes research, while providing training and support services for the study of the oceans and marine environments.

Initially, the Laboratory was hosted in Monaco's Oceanographic Museum. The Laboratory's subsequent, and its current permanent premises, were also provided by the Principality of Monaco, considerably expanding and enhancing the quality of laboratory space over this period, now named the Environment Laboratories. The Laboratory began its work by studying radioactive substances in the marine environment and their effects on marine life.

Unique data derived from the application of nuclear and isotopic techniques improve scientists' knowledge of oceanic processes, marine ecosystems and support pollution impacts assessments. These studies support the sustainable development of the ocean. The research is buttressed by strategic partnerships with other UN ocean agencies such as the Intergovernmental Oceanographic Commission, which also celebrates this year its 50th anniversary, as well as the United Nations Environmental Program, the United Nations Development Program (UNEP), the United Nations Educational, Scientific and Cultural Organization, and the International Maritime Organization.

Many Member States' national laboratories rely upon the Laboratory's accurate analyses of sea water, sediment and marine life samples. These analyses help assure the quality of the research conducted by collaborating laboratories engaged in joint environmental studies, utilizing the IAEA's reliable reference materials at an affordable cost.

In Monaco, the Radiometrics Laboratory uses radionuclides as environmental tracers, in collaboration with leading research centres around the world, to quantify ocean circulation, the transport of pollutants in coastal ecosystems, sedimentation and submarine groundwater discharge.

The Radioecology Laboratory studies the impacts of contaminants on seafood safety (including Harmful Algal Blooms), of climate change and ocean acidification on marine organisms, as well as the ocean's ability to sequester CO_2.

Two years after UNEP was founded in 1972, the Laboratory provided the essential scientific and analytical support for a landmark study of radioactive and non-radioactive pollutant levels in all principal seas. The Laboratories have undertaken worldwide radioactivity baseline studies of the Atlantic, North and South Pacific, Indian, Arctic and Antarctic Oceans and the Far Eastern, Mediterranean, and Black Seas. Regional studies have been conducted in the Gulf, the Irish, Kara and Caspian Seas, New Caledonia and the Mururoa and Fangataufa Atolls.

By 1986, the Marine Environmental Studies Laboratory was established in Monaco. This Laboratory is concerned mainly with non-radioactive pollutants such as pesticides, polychlorinated biphenyls (PCBs), petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), antifouling paint booster biocides, and recently also dealing with radioactive contaminants. In cooperation with regional laboratories, the Laboratory provides training and implements marine monitoring programmes, while acting as the analytical support centre for regional organizations protecting marine environments.

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Staff of IAEA's Environmental Laboratory contributed to this article.

marine

**By 1986, the Marine Environmental Studies Laboratory was established in Monaco.
This Laboratory is concerned mainly with non-radioactive pollutants radioactive contaminants.** (Photos: IAEA)

laboratory

by Maureen MacNeill

Unlocking Rain's Secrets

In March 1960, the World Meteorological Organization (WMO) and the IAEA began their cooperation: WMO meteorological services and other national agencies started collecting rain water over 50 years ago and continue to send samples to the IAEA and other cooperating laboratories, where the samples' isotopic content is determined.

Naturally ocurring isotopes in water help researchers trace the sources, movement and history of water molecules in the water cycle. Isotopes in precipitation are particularly useful tracers since precipitation recharges — directly or indirectly — all freshwater systems. Already in the late 1950s, the IAEA recognized that countries with limited water resources would need reliable and comprehensive hydrological information to be able to plan drinking water supplies as well as agricultural and industrial water consumption.

The resulting database, the Global Network of Isotopes in Precipitation, or GNIP, helps scientists profile the characteristic isotopic signature of precipitation, which is the key to interpreting environmental isotopes when assessing water resources. The database provides unique information and tools to understand atmospheric circulation processes and to verify and improve atmospheric circulation models, the study of climate change over different time periods, as well as for ecological research. The database is now routinely used in palaeontology, landscape ecology, anthropology, plant physiology, animal migrations, food webs, food authentication and forensics.

Today, the network contains isotope data for more than 900 stations, with over 120 000 monthly records. GNIP is the world's largest database of isotopes in atmospheric waters, available to all Member States to support isotope techniques for hydrological and atmospheric research, while the IAEA laboratory assists countries in determining the isotope composition of water samples to assess present and future water supplies.

This newsletter offers more information on GNIP's history: www-pub.iaea.org/MTCD/publications/PDF/Newsletters/WE-NL-26.pdf

Today, GNIP includes about 900 stations, producing over 120 000 monthly records. Below: Map of WMO stations contributing GNIP data, 1964, IAEA.

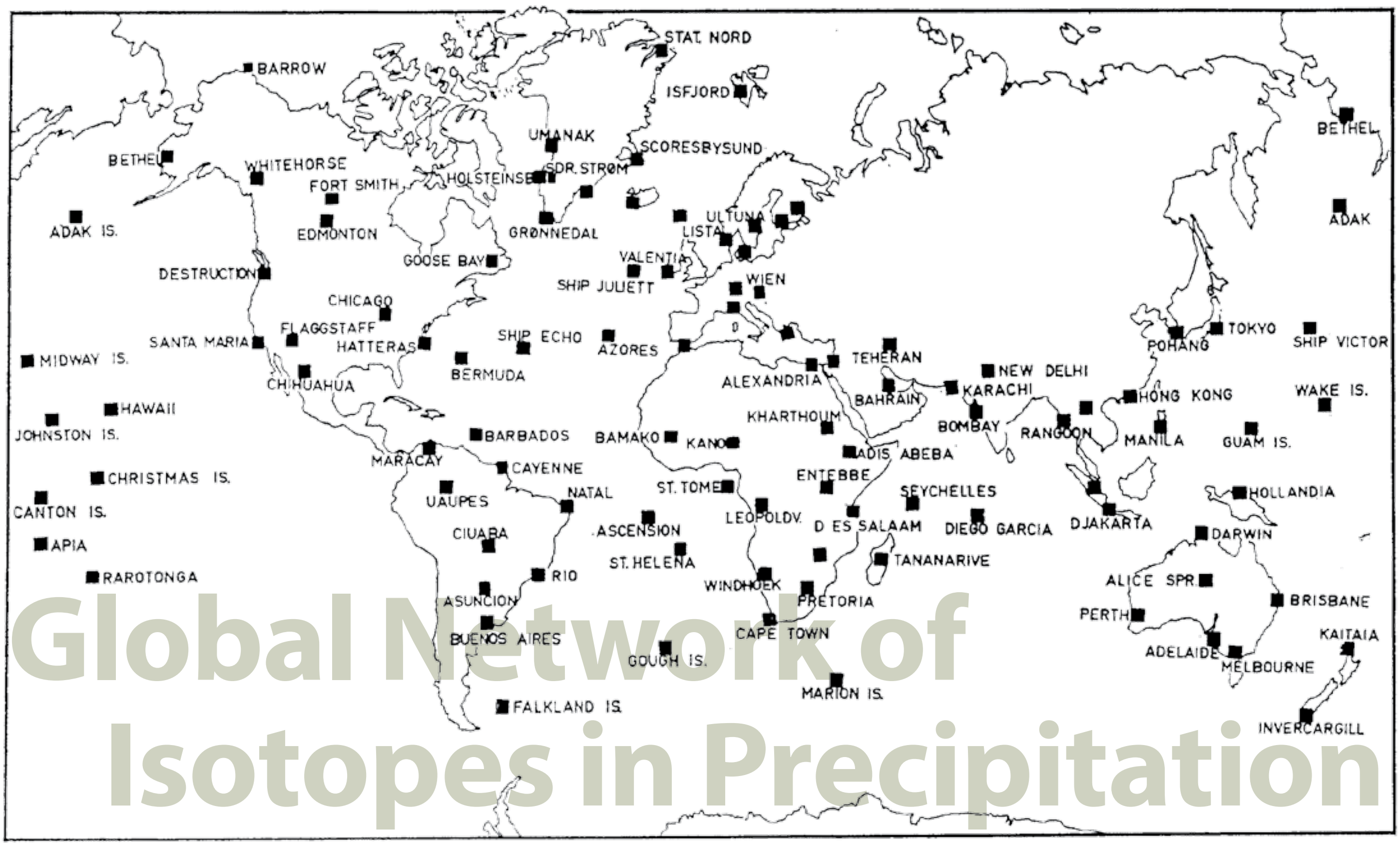

Photo: Caribbean surf lands at a beach near Puerto La Libertad, El Salvador.

The sea is never far from home. In fact, it's just two kilometres away from the homes of four out of ten people who live in the Caribbean region. Home to 14% of the world's coral reefs, the Sea boasts some of the planet's most diverse mangrove and sea-grass coverage, according to the United Nations' Environmental Programme (UNEP).

The reefs and coastal habitats support fisheries, and attract tourists, providing Caribbean nations annual revenues of between $3.1 and $4.6 billion.

The continued loss of coastal habitats and reefs can impede the region's economic and environmental resiliency. Pollution and sedimentation are two of the main threats to this delicate environment's health and diversity.

The IAEA is working with 12 Caribbean nations, providing support in the use of nuclear techniques to localize pollution sources and quantify their effects on coastal environments. Preserving the Caribbean's biodiversity is essential for regional development, according to UNEP's Caribbean Environment Programme.

Nancy Falcon Castro/UNIDO

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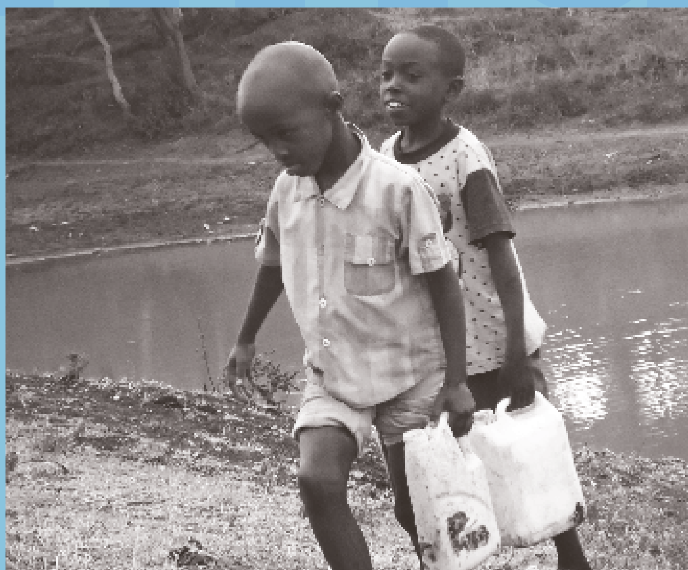
fetching water

an everyday story for a billion people



Eight-year old cousins, Mutuku and Mwania, live in Kimutwa in eastern Kenya. The rain-filled Kwa-Aka dam is their community's only water source. They walk five kilometers to reach the dam where they fetch water for their families. The water is polluted and needs to be boiled thoroughly before it can be consumed. Mutuku and Mwania built wooden barrows to haul the heavy water canisters home.

Water is scarce in this region; the rains are unpredictable and infrequent. People have few alternative water sources. When the dam water dries up, Mutuku, Mwania and others in their village will have to walk 20 km further to find water. A trek they will make until the rains refill the dam.

These photos were taken in June 2011, meanwhile the pond is empty. The next rain is expected in October.

Text: Louise Potterton ♦ Photos: L. Potterton & P. Pavlicek