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IAEA Water Resources Programme

Sampling in Uganda under an IAEA Coordinated Research Project on hydrological processes in wetlands (photo credit: Uganda Ministry of Water, Land and Environment, Directorate of Water Management).

From the Section Head

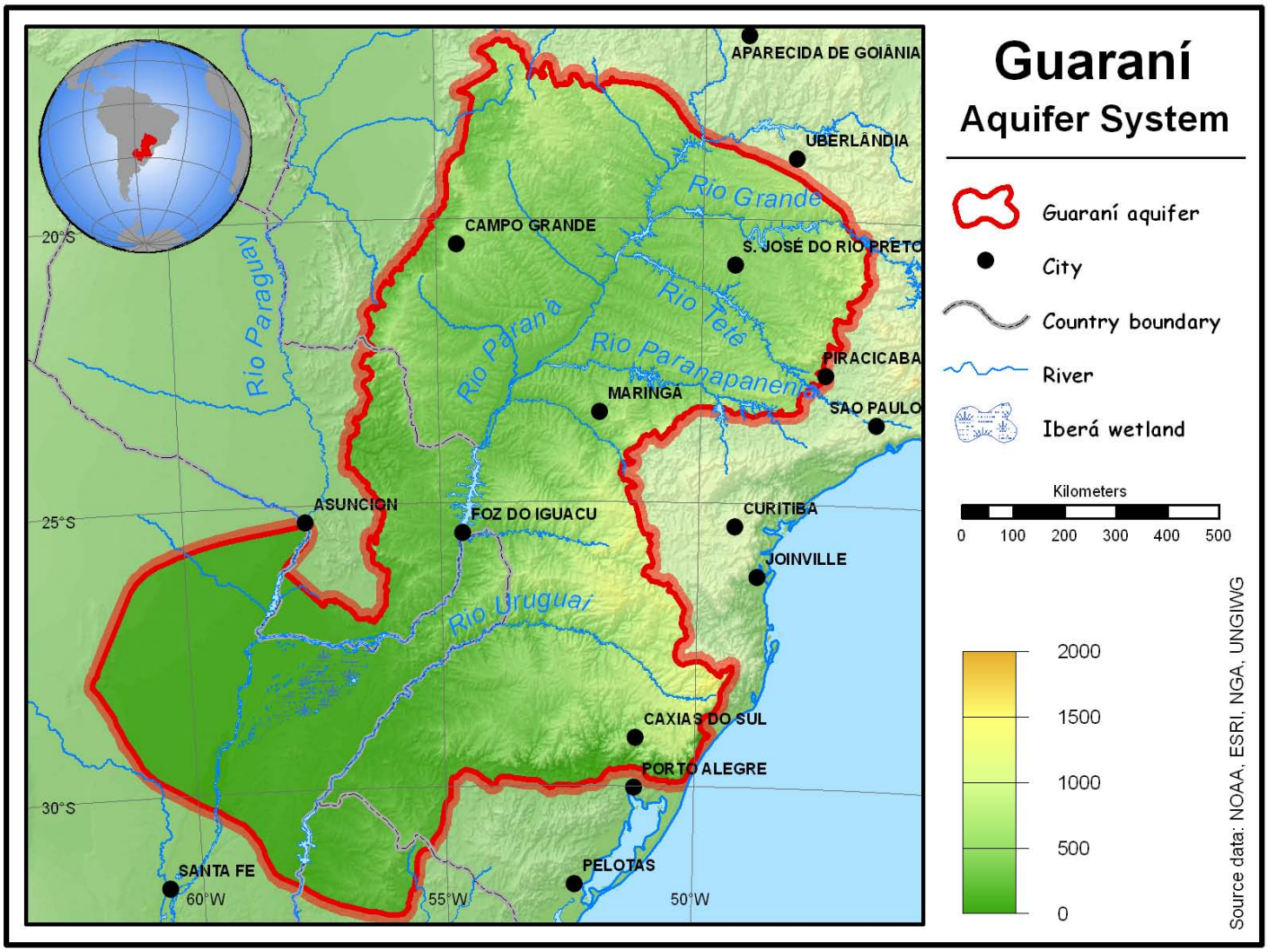
The IAEA Director General has selected Water to be his priority theme for 2011 in order to promote the role of IAEA in this field. The Director General intends to increase Member State awareness in this area of IAEA's work and strengthen partnerships with bi-lateral and other donor agencies. This is an excellent development for our programme and we aim to make use of this opportunity to help Member States integrate isotope hydrology into their water resource management efforts. To this end, we hosted a Side Event at the 2010 General Conference of the IAEA to inform Member States of the importance of using groundwater age for aquifer assessment and modelling of large, regional aquifers. Guest speakers included senior representatives from India and the USA. A 'water tasting' was held with water ranging in age from modern to approximately one million years and a physical model demonstrated the concept of groundwater age. The event attracted a large number of visitors and based on feedback from them, it is considered to be successful in conveying the intended message.

During this 'water year', the Section will focus on implementation of the IAEA's WAVE project . This project is aimed at comprehensive assessment of water resources. The first pilot study of this project will be conducted in the Philippines. After several years in development, the noble gas laboratory this year will begin to be used for a number of field studies to estimate groundwater age and recharge in shallow aquifers. We will also convene the quadrennial IAEA Symposium on Isotope Hydrology in March. This year's symposium will be held jointly with our Marine Environment Laboratory in Monaco on the occasion of the Laboratory's 50th anniversary. For more information on this event, find the link on our website at www.iaea.org/water. P. Aggarwal

Isotope Assessment of Guarani Aquifer a Major Step Forward in its Sustainable Management

By L. Araguas, M. MacNeill (IAEA)

A comprehensive hydrological study of the Guarani Aquifer system was completed recently, with maps, databases, models and reports produced. A Strategic Action Programme based on this information marks a significant milestone.



The Guarani Aquifer System is the largest groundwater body in South America and one of the world's largest aquifer systems. Though water quality is generally good, uncontrolled pollution in areas of extraction and recharge present the aquifer's principal threat.

The four countries overlying the Guarani Aquifer System (GAS), located primarily in the Paraná river basin, have made great advances recently in creating a management framework for this important aquifer. At over 1.2 million sq km and estimated to contain 37 000 cu km of water, this groundwater body is the largest in South America and one of the world's largest aquifer systems. It has the potential to sustainably supply about 360 million people, and currently supplies about 15 million in the region; the population of overlying countries Argentina, Brazil, Paraguay and Uruguay is collectively over 242 million.

GAS is an important water source for industry, agriculture, and to meet domestic requirements; it already supplies over 500 towns and cities. Though most of the reserves remain intact and groundwater quality is generally good, some areas of the aquifer are highly exploited, water consumption is rising, and the population is expanding. Uncontrolled pollution in areas of extraction and recharge present the aquifer's principal threat. A World Bank water resource

specialist recently stated that without better management, the Guarani aquifer is likely to suffer from pollution and rapid depletion and that uncontrolled exploitation could reduce it from a strategic water reserve to a degraded source.

A comprehensive hydrological study of GAS was completed in 2008, when maps, databases, reports and modes...were presented...

Completion of the Strategic Action Programme (SAP) in 2009 has marked a significant step forward for the sustainable management of this very important aquifer. The SAP provides a management framework, and was made possible through a collaboration of the four countries overlying the aquifer, with support from the Global Environment Facility (GEF), the World Bank and the Organization of American States (OAS). Together, these organizations began implementing the GEF-funded Guarani Aquifer Program for Groundwater Resource Sustainability and Environmental Protection in 2002. A comprehensive hydrological study of GAS was completed in 2008, when maps, databases, reports and models produced during the project were presented, and the SAP was based on analysis of this information.

The IAEA became actively involved in the project at a very early phase. The GEF and countries involved sought help from the IAEA to assess the aquifer using isotope hydrology. The IAEA assisted by providing technical assistance on the use of isotope and hydrochemical tools in characterizing the main hydrogeological features of the aquifer. Combined with other hydrological information, isotopic details have been able to complete a much needed assessment of aquifer characteristics in order to provide a thorough understanding of the GAS as well as a scientifically sound basis for management decisions. While the SAP provides the first step towards successful management — and has done much to bring the four involved countries together on the issue — its proper implementation is essential. Each country involved is responsible for managing the aquifer under their respective constitutional frameworks.

Isotope techniques aid in assessment

Isotope techniques have helped the four cooperating countries assess contamination patterns and water quality, as well as to determine the age and origin of groundwater. Results of carbon-14 testing revealed that old groundwater exists in much of the aquifer. These results were supported by preliminary information gathered using chlorine-36 and uranium isotopes. Ancient water is particularly vulnerable to groundwater mining, so even though the aquifer also undergoes some present day recharge, an aquifer management strategy must take both of these situations into account. While some countries contain recharge areas, others contain significant discharge areas.

Delineation of major sectors within the GAS, characterization of recharge areas and mechanisms of shallow and deep parts of the aquifer, and groundwater dynamics have all been determined using isotopes. The

Taking samples from the Guarani Aquifer in Argentina. (Photo credit: IAEA).

different hydrodynamic characteristics of the shallow (mostly unconfined) and deep (confined) parts have been defined. Important differences were found between the phreatic zones (with fast groundwater movement) and deeply confined units (with slow moving paleowaters) at the centre of the Paraná basin. Hydrochemical, isotope and hydrodynamic studies showed the existence of complex flow patterns in certain outcrop areas where local and regional flow lines of both recharging and/or discharging water coexist. Isotope research has proven that the GAS can be considered a continuous entity at the regional scale.

The conceptual model of GAS, revised from that created prior to the GEF undertaking, has important implications for the exploitation of groundwater. It has been determined that groundwater extracted from the unconfined part of the aquifer is fully renewable, however these areas are the most vulnerable to pollution and other impacts of human activity. Groundwater from the confined portion of the aquifer is economically feasible to extract to certain depths. These groundwaters normally have greater mineralization and are well protected from pollution, but extraction must be carefully planned since they are minimally recharged. Such information is very useful in helping the Guarani countries to work together on cooperative transboundary aquifer management.

The revised conceptual model of GAS has important implications for the exploitation of groundwater.

Compilation of information

An important outcome of this work has been the compilation of hydrological information for the four countries, which has been made available on a homogenized database. Isotopic, hydrochemical and hydrogeological databases have also been compiled and are publicly accessible. The IAEA's Water Resources Programme database, WISER, contains the complete isotopic and hydrochemical dataset. This sharing of information aids in building trust among the four Guarani countries.

More work needs to be undertaken in providing additional evidence for the aquifer's proposed main flow patterns. This would require more dating with long-lived environmental radioisotopes such as Krypton-81, as well as numerical modelling. Another issue, of even higher priority, is the identification of the actual mechanisms of discharge within the GAS. This issue is relevant for the consolidation of the conceptual model and has implications for water resource management. Possible groundwater discharge through some wetlands in the southern part of the aquifer is now being studied by groups in Argentina and Brazil as a follow-up to recent work carried out within the IAEA/GEF project.

For further information contact L. Araguas at L.Araguas@iaea.org

Demands on the Guarani Aquifer are growing; it is already an important water source for industry, agriculture and to meet domestic requirements (Photo credit: IAEA).

Water Resources Programme Side Event Includes Old Water and New Information

By M. MacNeill (IAEA)

The Water Resources Programme held a side event as an activity of the 2010 annual General Conference (GC) to inform attendees about the science of isotope hydrology and provide insight into upcoming themes and target areas.

The panel of speakers at the GC side event included prominent scientists and politicians, who discussed the role of isotope hydrology in their countries and the situation of groundwater at the international scale. A display illustrates the speed at which water moves through aquifers depending on the mediums involved, offering onlookers a simple way to grasp the concept of water residence time. After speeches were heard, attendees had the opportunity to taste 'old' water. (Photo credit: IAEA).

A large audience attended the Water Resources Programme side event — held as an activity of the annual IAEA General Conference — and took the opportunity to taste 'old' water. The side event highlighted upcoming activities and exciting developments in the areas of water resources assessment and transboundary aquifers.

Attendees of the event, held on 23 September 2010 in conjunction with the 54th General Conference (Sept. 20–23), got to taste million year old water, compare it to the taste of 'younger' water and find out how isotopes are used to determine the age of water. Vienna tap water (aged 5–10 years and dated using tritium) was compared to Austrian bottled water (aged 35 000 to 40 000 years and dated using radiocarbon) and African Nubian Aquifer water (aged about 1 000 000 years and dated using krypton-81).

How does water move through an aquifer? Visitors were able to observe the movement of water through mediums of different porosity through a small scale simulation of real aquifers.

The side event was well-attended, and guest speakers included Dr. Srikumar Banerjee, Chairman of the Atomic Energy Commission of India, HE Ambassador Glyn Davies, Permanent Representative of the United States of America to the International Atomic Energy Agency and the United Nations Office in Vienna, Mr. Fortunato de la Peña, Undersecretary of the Department of Science and Technology in the Philippines, and Mr. Wilhelm Struckmeier, President of the International Association of Hydrogeologists.

New IAEA WAVE initiative

Much discussion focussed on a new IAEA initiative, called the Water Availability Enhancement Project (WAVE), which will enable Member States to enhance the availability of fresh water through comprehensive, scientifically sound resource assessments. The project will assist Member States in identifying gaps in existing hydrological information and

understanding to improve national capacities for collecting, managing, and interpreting water resources data, and to use advanced techniques to stimulate hydrological systems for resource management. Another topic of the side event was groundwater assessment — an area of focus for the Water Resources Programme — particularly of regional and transboundary aquifers.

Former Deputy Director General and Head of the Department of Nuclear Sciences and Applications at the IAEA, Werner Burkart, welcomed the visitors, while Head of the Isotope Hydrology Section, Pradeep Aggarwal, introduced the guests, who unanimously recognized and supported the IAEA's water resources activities in their speeches.

Strong support

US Ambassador Glyn Davies stated in his speech that, "I applaud the Agency for its hard work…The IAEA's role in water resource management is an important and unique one, and one my country will continue to support.

"Water scarcity has profound implications not just for the people struggling to overcome it, but also for states endeavouring to achieve peace and stability. For this reason, water is and will continue to be a key issue for the United States."

He added, "The IAEA's efforts to improve access to safe water are diverse. The Agency has recently helped countries acquire isotope analysis machines that allow us to better understand water availability, sustainability, quantity and quality…The IAEA has also been actively advancing the mapping of groundwater resources, a difficult task that requires substantial experience, time and funding. The United States is committed to IAEA groundwater mapping projects."

"The US Department of Energy's Argonne National Laboratory has collaborated with the IAEA to focus on training in the area of isotope hydrology…Through the Peaceful Uses Initiative, the United States will continue to support the Agency's water programmes…the aim of this 100 million dollar effort is to strengthen the IAEA's ability to promote the peaceful uses of nuclear energy, including in the area of water."

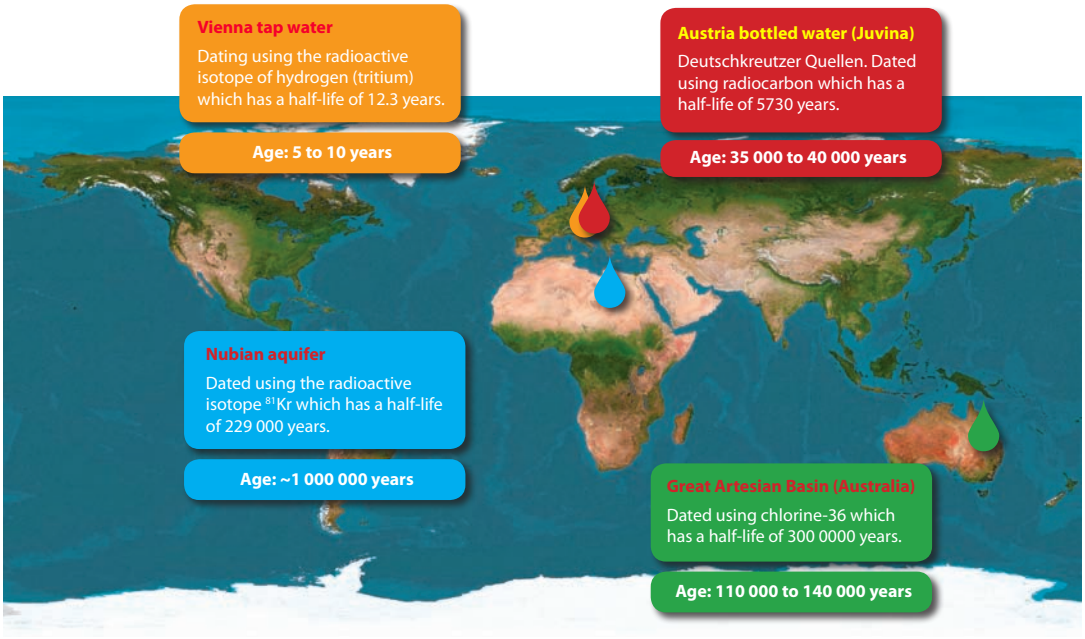
'The IAEA's role in water resources management is an important and unique one, and one my country will continue to support.'
— Davies

Dr. Banerjee gave accounts of Water Resources Programme successes in his country, stating that he has seen villages turn from desperate to prosperous based on projects supported by the IAEA in his country.

Philippine Undersecretary of the Department of Science and Technology Mr. Fortunato de la Peña stated how pleased he is that the Philippines is the first collaborating pilot country in the IAEA WAVE initiative currently being undertaken by the Water Resources Programme. He stated that there are many gaps in information in his country that nuclear technology can contribute to filling so that a proper assessment can be provided of water resources, thus improving water management.

Mr. Struckmeier discussed the international outlook for groundwater, using detailed maps to highlight issues and provide information about the situation as it is today and may be in the future, as well as the contribution of IAEA projects to mapping groundwater resources.

The event closed with a tasting of waters of different ages.



Map showing the ages of different groundwaters tasted during the side event, and for which isotopes were used to determine groundwater age.

New DDG visits Isotope Hydrology Lab

The new Deputy Director General of Nuclear Applications, Mr. Daud Bin Mohamad (left), is taken on a tour of the Isotope Hydrology Laboratory by head of the Isotope Hydrology Section, Pradeep Aggarwal. (Photo credit: IAEA).

IAEA WAVE receives funding boost from PUI

The IAEA Water Availability Enhancement Project has received funding support for 2011 from the Peaceful Uses Initiative (PUI) of the US Departments of State and Energy. Water resource management is one of four areas in which the PUI will provide training, equipment, and technique development. The goal of the PUI is to expand countries' capabilities in specific ways to allow them to use nuclear technology for peaceful purposes.

Philippine Undersecretary of the Department of Science and Technology Mr. Fortunato de la Peña stated how pleased he is that the Philippines is the first collaborating pilot country in the IAEA WAVE initiative currently being undertaken by the Water Resources Programme.

PUI funds will be used to complement existing planned Water Availability Enhancement Project activities, to advance proof-of-concept evaluation of pilot studies, and to enable the meeting of project goals within an accelerated timeframe. The initial pilot study, in the Philippines, has reached the following goals:

- A preparatory study has been done, providing basis for a preliminary mission to the Philippines;
- A preliminary mission has been conducted to the Philippines August 30 through September 3, 2010 at which the represented Philippine water agencies agreed to undertake a IAEA WAVE project pilot study, and the National Water Resources Board (NWRB) was selected as the lead agency to coordinate the cooperative IAEA pilot study;
- A National Workshop is planned for the first week of March 2011, at which the NWRB plans to gather input from about 90 national and regional water professionals to finalize and prioritize a list of hydrological gaps, complete detailed profiles of each gap, and begin development of a work programme for the Hydrological Gap Plan. The IAEA has assembled a team of international technical experts that will participate in the workshop to support project goals.

For further information contact C. Dunning at C.Dunning@iaea.org

Isotopic Techniques in the Assessment of Coastal Aquifers in Latin America

By L. Toro Espitia, L. Araguas (IAEA)

A Regional Technical Cooperation Project used isotope techniques to complement conventional hydrological tools in uncovering groundwater dynamics and the origin of salinization.

Map of the coastal aquifers studied in the Application of Isotopic Tools for Integrated Management of Coastal Aquifers project.

Coastal aquifers play a crucial role in the economy and welfare of many regions in Latin America because in many cases they constitute the only source of drinking water in littoral areas (usually with a population density twice that of the interior of the continent) as well as providing support for many industries, including agriculture and tourism. These aquifers also share many problems, such as being prone to seawater intrusion if the level of groundwater extraction exceeds their recharge rate. Nevertheless, coastal aquifers also exhibit many differences in relation to each other; for example, in their matrix (unconsolidated sediments and sedimentary porous media aquifers vs fractured elements); their hydraulic properties (groundwater flows from a few millimetres per day in fine-grained sediments up to hundreds of meters per hour in karst terrains); interactions with other water bodies (absence or presence of hydraulic connections with the sea, lakes, rivers or other aquifers); and in their water chemistry.

Regional Project

A Regional Technical Cooperation Project entitled Application of Isotopic Tools for Integrated Management of Coastal Aquifers (ARCAL XCII, RLA/8/041) was conducted from 2007–2010 with the support of the IAEA; the goal was to improve the capacity of Latin American Member States to assess the dynamics of coastal aquifers by means of the application of isotope techniques as a complementary tool to more conventional hydrological techniques like hydrochemistry, geology and well hydraulics. The seven study cases in this project covered a wide range of approaches and sites typically encountered in coastal environments. Areas of study included small alluvial aquifers hydraulically connected to the sea (Parrita and Huacas-Tamarindo aquifers, Costa Rica) or recharged by adjacent sedimentary and metamorphic geological units (region of Mancora in northern Peru); karst terrains (southern basin, province of La Habana, Cuba); aquifers in semiarid areas (Santa Elena Peninsula, Ecuador); and aquifers with pollution problems (Mar del Plata in Argentina and La Paloma in Uruguay); see map on previous page.

Final Coordination Meeting

The final coordination meeting was held at the Escuela Politécnica del Litoral (ESPOL) headquarters in

Final coordination meeting held in the headquarters of ESPOL, Guayaquil, Ecuador.

Guayaquil, Ecuador, 11–15 October 2010, and was attended by representatives of Spain as a donor country (Centre for Energy, Environment and Technology — CIEMAT), the IAEA, and the six participating countries: Mar del Plata University (Argentina), National Service for Groundwater, Irrigation and Drainage — SENARA — (Costa Rica), Centre for Technological Applications and Nuclear Development — CEADEN — (Cuba), ESPOL (Ecuador), University of Piura (Peru), and Obras Sanitarias del Estado — OSE — (Uruguay).

A broad set of tools, including hydrochemistry, stable isotopes of water and the nitrate ion, tritium dating, and other groundwater tracers were used to study groundwater dynamics, hydraulic connections and in some cases the origin of salinization. The project was able to determine the current status of seawater intrusion in two aquifers affected by the process of salinization. The interaction between surface waters and shallow aquifers has also been assessed. The main results have been synthesized into reliable conceptual hydrological models; in the case of Argentina, it has been possible to develop a numerical model of flow and transport.

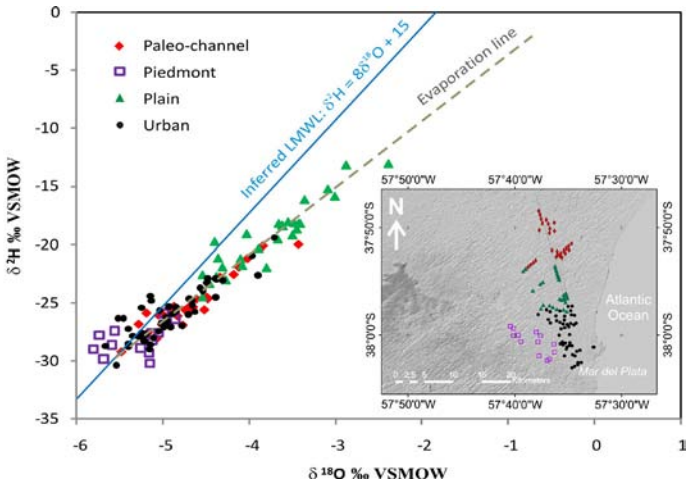
The figures on the right show two of the most outstanding achievements. Deuterium and oxygen-18 were used to characterize the main recharge processes in the Mar del Plata region, Argentina (top figure). The isotope data in the plain area is distributed along a single evaporation line, but the location of each sample on this line depends on how quickly recharge occurs. Thus, it has been possible to identify areas with fast and slow infiltration (foothills and plains, respectively). Other areas, such as urban and some paleo-channels, show intermediate characteristics.

In the Parrita basin, Costa Rica, stable isotopes and chemistry have shown that wells located in a band of about one kilometre wide on both sides of the main stream contain a mixture of river water and locally recharged groundwater (bottom figure). For wells located outside of this area, it was shown that the influence of the river water is negligible. Chemical and isotopic data illustrate seasonal changes in response to dry and rainy periods, which indicates that the system is very dynamic. For example, groundwater during dry periods tends to be saturated in calcite, while during rainy seasons it is clearly sub-saturated due to the increased presence of recently infiltrated water (local rainfall, river water, or both).

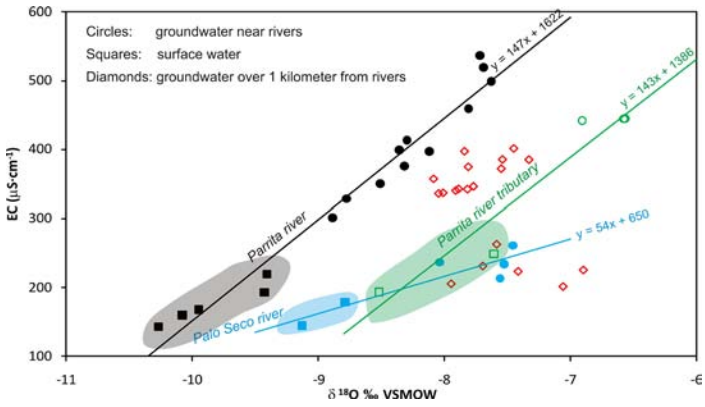
Applying the information

The understanding acquired is being used by local authorities in the Argentinan study areas to aid in making projections on how to meet the future water demands of domestic users and the agricultural sector, while Costa Rica is developing vulnerability maps. It is expected that in the near future, knowledge gained by the other countries can be incorporated into management plans of the aquifers under study. Details of chemical and isotopic information obtained during project implementation will be included in an IAEA technical publication.

For further information contact L. Toro Espitia at L.Toro-Espitia@iaea.org



Deuterium and oxygen-18 in Mar del Plata aquifer (modified from Bocanegra et al., in prep.).



Oxygen-18 vs. electrical conductivity in Parrita aquifer (from Matamoros and Toro, in prep.).

First Helium CRP will Develop and Test Tools to Improve Groundwater Assessment

By L. Araguas, M. MacNeill (IHS, IAEA)

Participants at the first Research Coordination Meeting on Tritium-^{3}He dating and Noble Gas Techniques in Water Resources Management: Recharge, Infiltration Conditions and Groundwater Balance.

Tracers of groundwater flow are especially important for understanding hydrological systems, ranging from small local catchment areas to large regional basins. Isotope tracers are valuable tools which can provide key information on groundwater dynamics, as well as direct recharge rate estimates for groundwater renewal.

The Water Resources Programme held the first Research Coordination Meeting (RCM) on 'Tritium-^{3}He Dating and Noble Gas Techniques in Water Resources Management: Recharge, Infiltration Conditions and Groundwater Balance' on 8–12 Nov. 2010 to focus on this area under Coordinated Research Project (CRP) 1786.

The ^{3}H/^{3}He technique combines time dependent tritium input from atmospheric water with tritium decay into ^{3}He in groundwater. The main advantage of this tool is that it is independent of local infiltration conditions and the input function of tracers, thus it can provide direct information on groundwater age in a recharge zone, and it remains unaffected by significant contamination sources. The ^{3}H/^{3}He technique can also be used to investigate discharge areas where groundwater seeps out into rivers, creeks, springs or lakes, enabling estimates of groundwater residence time in a larger catchment area by measuring a few samples at the discharge area.

Analytical facilities at the IAEA and recent advances in sampling techniques for $^{3}H/^{3}He$ create a good environment for advanced sampling campaigns.

The overall objective of the CRP is the development and testing of $^{3}H/^{3}He$ methodologies to improve assessments of groundwater recharge and discharge rates through dating and direct assessment of groundwater turnover time via $^{3}H/^{3}He$ and associated tracers. The turnover time of a groundwater reservoir is directly related to volume and sustainable yield. The results will therefore contribute to sustainable management of groundwater resources and will be relevant to establishing hydrological baselines for evaluating land use and climate change effects. In addition, Member States' capacity in using environmental tracers for groundwater dating will be strengthened.

Research objectives include:

- Evaluating the usefulness of the $^{3}H/^{3}He$ isotope technique for estimating recharge rates of aquifers in different hydrogeological settings;
- Evaluating the use of $^{3}H/^{3}He$ isotope age dating for understanding groundwater–surface water interactions and groundwater discharge as baseflow to rivers and other surface water bodies;
- Evaluating the performance of different sampling techniques to provide guidelines for the optimal use of the $^{3}H/^{3}He$ technique;
- Comparing evaluated recharge and discharge estimates with conceptual models and validating methodology used with existing hydrological data and simplified groundwater flow and transport models.

Expected outputs include:

- Assessment of the degree of success of the $^{3}H/^{3}He$ method in quantifying recharge rate and discharge flow estimates for selected study areas, in conjunction with other environmental tracers;
- Establishment of guidelines for appropriate $^{3}H/^{3}He$ sampling techniques in different hydrogeological settings;
- Comparison of environmental tracer based recharge rates and groundwater ages with those obtained through application of other methods and approaches, including numerical modelling;
- Information transfer using suitable tools for further application in Member States such as technical publications and an IAEA-TECDOC.

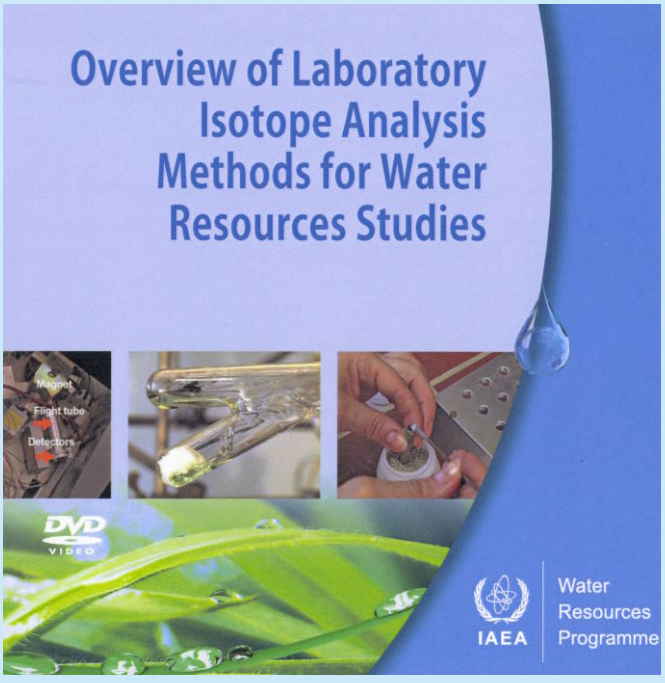
New Laboratory DVD Released

The Isotope Hydrology section has released a DVD-video entitled, Overview of Laboratory Isotope Analysis Methods for Water Resources Studies in November 2010.

This DVD shows actual examples of how stable and radioactive isotope measurements are conducted in the laboratory. There is an overview of laboratory methods used in the preparation and analysis of deuterium, oxygen-18, carbon-13 and carbon-14. Noble gases, tritium and CFCs are included in separate sections.

Many analytical details are covered, allowing a view into individual methods so the user can gain an in-depth understanding of how to conduct isotope analyses in the laboratory. This DVD will also aid laboratory analysts interested in conducting specific types of isotope measurements as well as users of isotope data who would like to know more about how isotope measurements are conducted. A flash version of this DVD is accessible on the Isotope Hydrology Section website (www.iaea/water.org).

For further information please contact B. Newman at b.newman@iaea.org or T. Kurttas at t.kurttas@iaea.org



Workshops Build Capacity for Nile countries

Participants of a regional training workshop held in Vienna from 18-20 October, 2010.

A technical meeting was held held in Vienna 18-20 October 2010 on integrating isotope data in rainfall-runoff models. The meeting was convened to advise the IAEA on the current and emerging practices in catchment hydrology. While their findings have no particular geographic emphasis, the results are well timed to support the IH section's work with Nile basin countries to model groundwater interactions with the lakes, wetlands, and river reaches of the Nile River.

The Isotope Hydrology Section and Technical Cooperation Department has also conducted training workshops in Addis Ababa, Ethiopia and Cairo, Egypt to support Nile Basin countries. These two week workshops were part of the project Mainstreaming Groundwater Considerations into the Integrated Management of the Nile Basin, funded by the Global Environment Facility and IAEA Technical Cooperation (RAF8042). A primary goal of the project is to understand the role groundwater plays in the water resources of the Nile Basin through a series of water balance models. Training to build capacity within water ministries, universities, and other national and regional institutions helps place as much of the activity of this project as possible at the national or regional level.

Isotope fundamentals

The first course, entitled, Regional Training Workshop on Basic Isotope Hydrology, was held from 15–26 November 2010 and hosted by the Earth Sciences Department at Addis Ababa University. The course covered the fundamentals of water and carbon isotopes, water chemistry, geochemistry, and isotope mass-balance modelling. Instructors were Dr. Paula Carreira of the Nuclear and Technological Institute, Portugal and Dr. Yves Travi of the University of Avignon, France. A total of 22 participants attended from all nine of the Nile Basin countries participating in the project, which are (from upstream to downstream), Burundi, Rwanda, Democratic Republic of the Congo, United Republic of Tanzania, Kenya, Uganda, Ethiopia, Sudan, and Egypt.

While the first workshop covered basic isotope hydrology, the second workshop considered more directly the use of stable isotopes water balance modelling. This course was held from 29 November to 10 December 2010 and was titled, Regional Training Workshop on Integration of Isotope Data in River Basin Water Balance Models. The workshop was hosted by the Research Institute for Groundwater, National Water Research Center, El Kanater, Egypt. The instructors for this workshop were Dr. Jeffrey MacDonnell of the University of Oregon, USA and Dr. George Leavesley of Colorado State University, USA.

Topics for this workshop included catchment and hillslope runoff modelling and how isotopes are integrated into these models and the use geographic information systems (GIS) to manage and process runoff models. As with the first workshop, this course was open to Nile basin countries participating in the project. Also invited, however, were participants from the Nile Basin Initiative (NBI). The NBI plays a key role in water resources management in the Nile basin and will be the beneficiary, along with the member countries themselves, of the results of this project.

Assessing Isotopes in Snow, Glacier and Permafrost Dominated Areas

Participants of the first RCM on Use of Environmental Isotopes in Assessing Water Resources in Snow, Glacier and Permafrost Dominated Areas under Changing Climatic Conditions.

Participants of a five day Research Coordination Meeting gathered in Vienna between 30 August–3 Sept. 2010 to discuss the 'Use of Environmental Isotopes in Assessing Water Resources in Snow, Glacier, and Permafrost Dominated Areas under Changing Climatic Conditions'.

Seasonal snow-cover occurs in about 25% of the Earth's land surface, at high latitudes and high altitudes. The storage of precipitation in snowpack and glacier, and the subsequent melting, substantially impact the water cycle. Recent climate warming and changes in atmospheric circulation patterns have resulted in reductions in the duration of the snow cover season, the amount of water stored in the snowpack, as well as a widespread trend toward earlier spring melt and enhanced glacier melting. Environmental isotopes have the potential to provide an innovative assessment of critical linkages between the discharge from snow and ice systems and rivers/aquifers. A new CRP has been started to test the use of isotope techniques for the assessment of snowpack, glaciers and permafrost to groundwater and surface water systems.

The CRP is aimed at assembling isotopic evidence for water derived from snowpack, glaciers, and permafrost, and at an isotope supported estimation of transit times of melt-water through snow and ice layers, residence times in the subsurface and travel times to rivers, lakes and water supply and water energy facilities. Applicability of the results will be identified across catchment scales and with emphasis on their extrapolation under changed climate conditions.

First Research Coordination Meeting of the CRP was held at IAEA Headquarters, Vienna, Austria from 30 Aug.–3 Sept. 2010. Counterparts/representatives of research groups from Argentina, Canada, Georgia, Germany, Italy, Japan, Morocco, Pakistan, Russian Federation, Slovakia, Slovenia and USA.

All of the groups have the general objective of using the distinct isotopic labelling of water to improve understanding of the role of snow, ice, glaciers and permafrost in runoff, either resulting in the development of conceptual models or quantification of the different components. More specific objectives include:

- Better characterization of the isotopic composition of different components of the cryosphere;
- Use of water isotopes tracers to better understand the role of the cryosphere in groundwater recharge;

- Use of water isotopes to detect climate change.

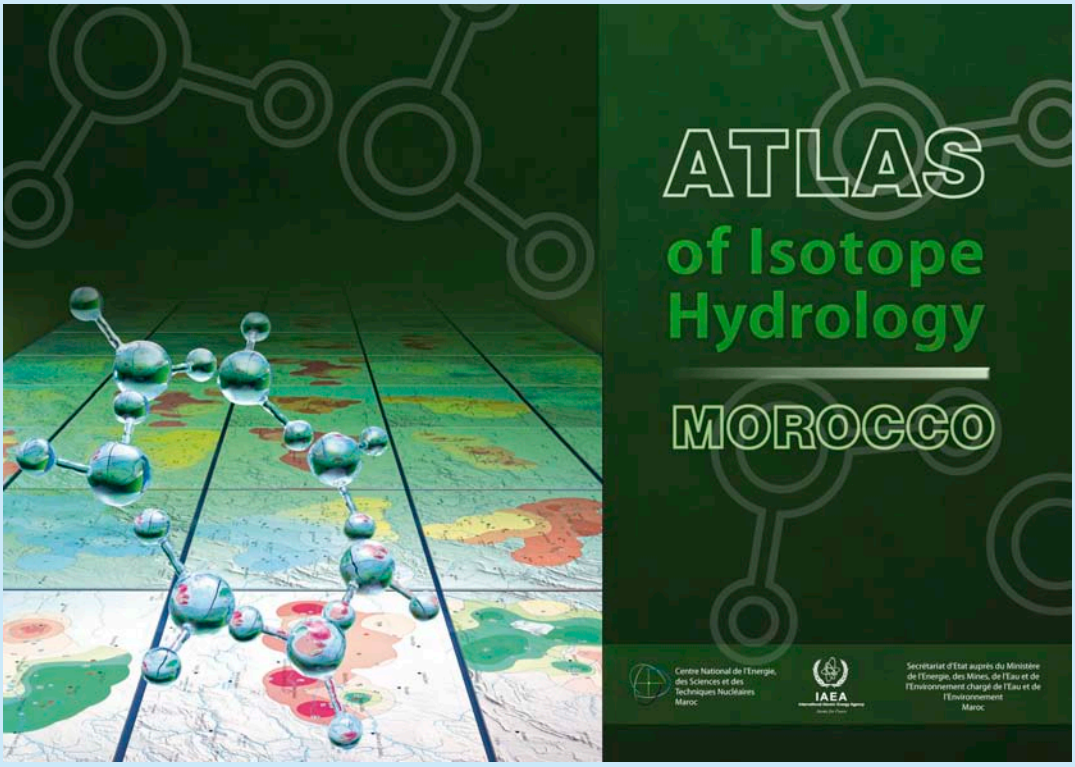
The objectives, methods and tools proposed by participants of the CRP vary according to the specific needs, resources and setting. The various projects proposed by the participants includes the application of isotopic techniques in a wide range in spatial and temporal scales at a variety of geographical settings, sharing the common element of having snow, ice, glaciers or permafrost as significant components of the hydrological budget. The proposed research projects can be divided into four main themes, with some proposals addressing multiple themes.

In general the proposals use the distinct isotopic labelling of different components of the water cycle to:

- Quantify the contribution of snow, glaciers and permafrost to the water budget of streams (Germany, Georgia, Italy, Pakistan, Slovakia, Slovenia and USA);
- Quantify the contribution of snow to groundwater recharge (Argentina, Georgia, Germany, Italy, Morocco, Pakistan, Slovakia, Slovenia);
- Provide more qualitative information to be used to refine conceptual models concerning the role of snow, glaciers, and permafrost to the water budget of a catchment (Canada, Japan);
- Improve characterization of the isotopic composition of different components of the cryosphere (i.e. permafrost, snow, snowmelt) (Canada, Italy, Japan, Russian Federation, Slovakia, USA).

The majority of the proposals presented were based on work to be conducted at the small basin scale, with only two groups working on large river basins (Canada, Japan). The proposed research will include studies using fairly intensive short term monitoring of isotope data with others focusing on long term monitoring.

Morocco Atlas summarizes investigations



The sustainability of groundwater resources for drinking water supplies, agriculture, and industry is a prime concern in countries dominated by arid and semi-arid climates such as Morocco. The growing demand for groundwater coupled with impacts from land use and climate change make sustainability an even more important water management goal. In order to make sound decisions about water use and protection of water quality, water managers and policy makers must have a sound understanding of such factors as the location and amount of groundwater recharge and groundwater ages.

Isotope methods can be essential for understanding how groundwater systems work in large, dry land basins and yield critical insights that standard hydrological or geochemical methods cannot provide. For many years the Morocco State Secretary in charge of Water and Environment, the Morocco National Centre of Nuclear Energy, Sciences and Technology (CNESTEN) and the IAEA have worked together to characterize groundwater basins in Morocco using isotope and nuclear methods. This Atlas summarizes the data and findings of ten different groundwater investigation projects. This is the fourth atlas released by the Water Resources Programme.

Hydrological Processes in Wetlands Investigated

Participants at the IAEA Coordinated Research Project on Isotopic Techniques for Assessment of Hydrological Processes in Wetlands meeting, held in Vienna from 6–9 September 2010. Missing from the picture: A. Tening, Cameroon, E. Bocanegra, Argentina.

The Third Research Coordination Meeting (RCM) of the Coordinated Research Project Isotopic Techniques for Assessment of Hydrological Processes in Wetlands was held in Vienna from 6–9 September 2010. Twenty researchers from 17 countries, including observers, participated in the meeting.

Wetlands provide an important link between water and land ecosystems and play a variety of roles, such as providing habitats and refuges for wildlife or flood protection, contributing to abatement of the impacts of pollution, and promoting groundwater recharge. The existence and maintenance of wetlands depends on hydrological processes in and around wetlands, but the processes involving wetlands have not been well understood, including human and climatic changes to hydrological balances and water quality in wetlands and their surrounding water bodies.

Purpose of the CRP

This CRP was started in 2006 to promote studies on complex water and solute flux processes with the application of isotope techniques, and to assist in collaboration among researchers studying those processes in and around wetlands. The primary purposes of the third RCM were: to review the progress of individual projects and activities conducted since the second RCM in 2008, to discuss and design the final output of the entire group and agree upon and modify the workplan to produce a final output, and to further promote cooperation and information exchange among researchers.

Through the development of individual projects and collaboration among researchers on these projects, including discussion from the previous three RCMs, participants identified the following seven topics, which were covered by this CRP: (1) fingerprinting (i.e., source/flowpath); (2) time indicators; (3) interaction between water bodies; (4) water balance; (5) element cycling; (6) chemical processes; and (7) biophysical indicators. Participants recognized that the reach and level of isotope applications in wetlands under this CRP were from various perspectives unprecedented, suggesting a potential for contributing to wetland science. Thus, participants agreed that it would be worth continuing to actively look for opportunities to highlight and publicize results of the CRP, through presentations at international conferences, for example.

Participants agreed their participation in the CRP brought positive results. For example, it provided an opportunity to network with other scientists, learn the use of conventional isotope techniques in new fields of wetland science, and the use of new isotope techniques in conventional wetland science. This CRP will continue to be active for about one more year and participants work to complete individual projects as well as this CRP as a group.

Sampling in the Czech Republic under an IAEA Coordinated Research Project on wetlands (photo credit: Czech Technical University, Faculty of Civil Engineering).

Many African Training Courses Undertaken

Participants to a workshop held in the Democratic Republic of Congo from 16 to 21 August, 2010 (photo credit:CGEA of DRC).

The summer and autumn of year 2010 were busy with training courses held in Africa, from basic to advanced levels, to pass on knowledge of the use of isotopes in hydrological studies. The courses are intended to help Member States become more independent in conducting studies of their own water supplies to improve management of these precious resources.

National Course in the DRC

A national training course on basic isotope hydrology was held in Kinshasa, the Democratic Republic of the Congo from 16 to 21 August 2010. This training course in isotope hydrology was organized by Commissariat Général à l'énergie Atomique (CGEA) as the project counterpart and the IAEA through national Technical Cooperation (TC) project ZAI8013, entitled Isotope-based Hydrogeochemical Studies of the Mont Amba Aquifer. Twenty-three fellows working in hydrological research or water resource management or teachers in the above-mentioned fields participated in this training course, taught by H. Marah of Morocco and J. Ndembo Longo of CGEA. The training course covered: (a) basic isotope hydrogeology and hydrochemistry of natural waters; (b) water balance and hydrological processes; (c) use of environmental isotopes in assessment of stream/aquifer interactions in catchments and shallow groundwater systems; (d) the use of hydrochemical and isotopic methods in assessment of groundwater flow, origin and age; and (e) an overview of field sampling and monitoring methods in isotope hydrology.

This training course.... (is) meant to develop Africa's capacity and self-reliance in integrating isotope techniques in the planning, development and sustained management of water resources in the region...

Regional Course, Morocco

A regional training course on Quality Assurance and Quality Control for Water Sampling and Isotope Analysis in Isotope Hydrology was held at Centre National de l'Energie, des Sciences et des Techniques Nucléaires (CNESTN) in Rabat, Morocco from 25 October to 5 November 2010. This training course was organized through regional Technical Cooperation (TC) Africa project RAF8048, entitled 'Building Capacity in Support of Regional and Sub-Regional Water Resources Planning, Development and Management in Africa.' under the African Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA) programmes.

This training course was the second course in a training programme meant to develop Africa's capacity and self-reliance in integrating isotope techniques in the planning, development and sustained management of water resources of the region, following the first training course on basic isotope hydrology in Addis Ababa in 2009. The purpose of the training course on QA/QC for water sampling and isotope analysis in isotope hydrology was to assist in the acquisition of practical knowledge and experience in conducting field and laboratory works in isotope hydrology, which is the basis for water resource investigation and management.

The training course, taught by H. Marah of CNESTN and S. Kebede of Ethiopia, consisted not only of classroom lectures and exercises, but also actual field and laboratory activities. Twenty-seven fellows from Burkina Faso, the Democratic Republic of the Congo, Egypt, Ghana, Kenya, Madagascar, Mali, Namibia, Niger, South Africa, Tunisia, Uganda, and Morocco participated in this training course, and conducted exercises on the sampling of rain and surface waters, as well as groundwaters. They also participated in laboratory activities, includingng the analyses of stable water isotopes, tritium and carbon-14 of water samples.

Participants at a regional training course in Morocco on "Quality Assurance and quality control for water sampling and isotope analysis in isotope hydrology (photo credit: CNESTN).

Training Course in Ghana

A national training course on the application of tracer methods and modelling in isotope hydrology was held in Accra, Ghana from 25 October to 5 November 2010. This training workshop was organized by the National Nuclear Research Institute of the Ghana Atomic Energy Commission (GAEC) and the IAEA through national TC project, GHA8009, entitled Integrating Isotope Techniques in the National Groundwater Resources Assessment Plan. Ghana has much experience in isotope hydrology, having completed three national TC projects and three regional TC projects in this area. The country is involved in two ongoing regional TC projects in isotope hydrology, in addition to this current national project (GHA8009), and has been making an effort to move to an advanced level based on knowledge and experience in basic isotope hydrology.

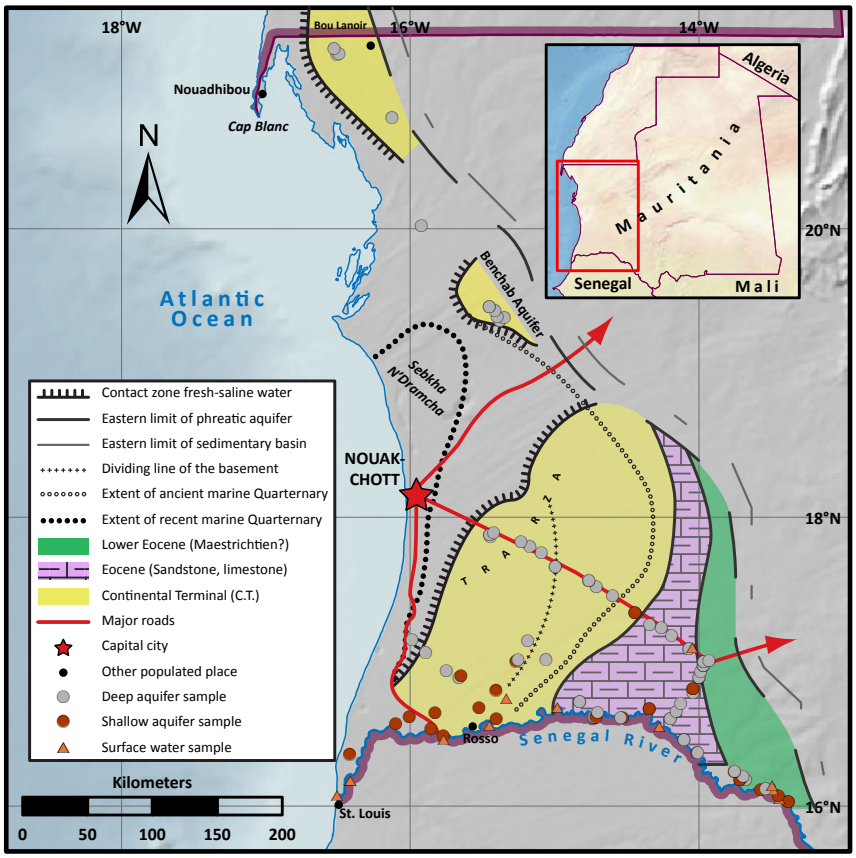
A national training course was held in Ghana on the application of tracer methods and modelling in isotope hydrology (photo credit: GAEC, National Nuclear Research Institute).

The purposes of this national training course were to understand the concept of tracer methods and modelling in hydrology and hydrogeology in general and isotope hydrology in particular, and to acquire the practical knowledge and skills necessary for conceptual and numerical modelling in hydrogeologic studies with the application of isotope techniques, especially to cases in Ghana. Twenty-three fellows participated in this workshop, taught by Piotr Maloszewski and consisting of lectures on the application of environmental and artificial tracers and intensive exercises to estimate hydrological and transport parameters and characterize flow and tracer transport.

Studies on Groundwater in Mauritania

By Ould Med El Hacen Saadou Ebih, Assana Ousmane Gaye, Bacar Y Sidi Haiba, Ministere de l'Hydraulique de l'energie et des TLC, Centre National des Ressources en Eau (CNRE), Nouakchott, Mauritania,
K. Zouari, Université de Sfax, École nationale d'ingénieurs de Sfax, Département de génie géologique, Laboratoire de Radio-Analyse et environnement (LARAE), Sfax, Tunisia, M. Ito (IAEA)

Research into the characteristics of Mauritania's deep and shallow groundwater has uncovered valuable information for local authorities, so they can better understand their water resources.



Map of the study area in the Trarza Basin area of Mauritania.

Mauritania, located in the southwestern Sahara in northwestern Africa, is about 1.04 million square km in size. The country has 592 km of coastline on the Atlantic Ocean. Mauritania is predominantly desert, and much of the country receives less than 300 mm per year of rainfall. For supply water, the country highly depends on surface water in the south from the Senegal River, which is shared by Guinea, Mali and Senegal, or on the utilization of groundwater. In the capital Nouakchott, where one quarter of the country's population lives, daily water delivery is about 50 000 m^3, far below the estimated base line of 95 000 m^3 (FAO, 2002). The available surface water is irregular in quantity and the quality is under threat since groundwater is suspected to be affected by pollution and salt intrusion. The supply of potable water is thus one of the priorities for economic and social development in the country.

Technical Cooperation Projects

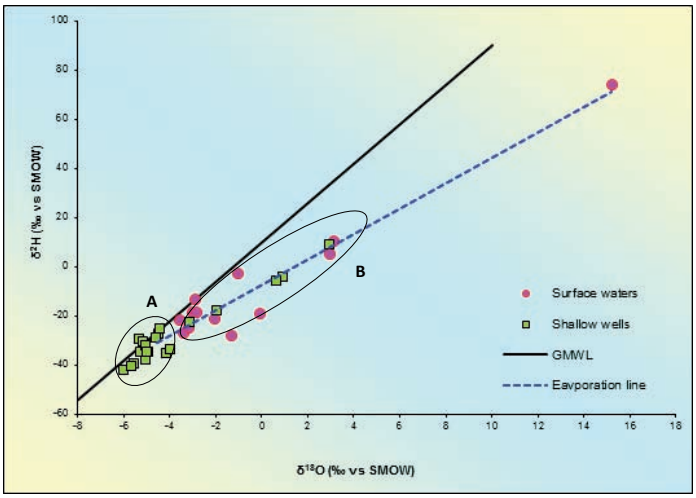
The first technical cooperation project in isotope hydrology in this country was started in 2007 and is being implemented by Centre National des Ressources en Eau (CNRE) of Ministere de l'Hydraulique de l'Energie et des TLC in cooperation with Ministère de la Défense Nationale Etat-Major National Direction du Génie Militaire. This project is entitled Use of isotope hydrology techniques for the study of the Trarza's Aquifer and discontinued aquifers in southern Mauritania (MAU8002). The first phase aims to better understand and manage the Trarza aquifer, located in the Mauritanian coastal basin, which includes Nouakchott, in order to help improve information on the water resources in the region.

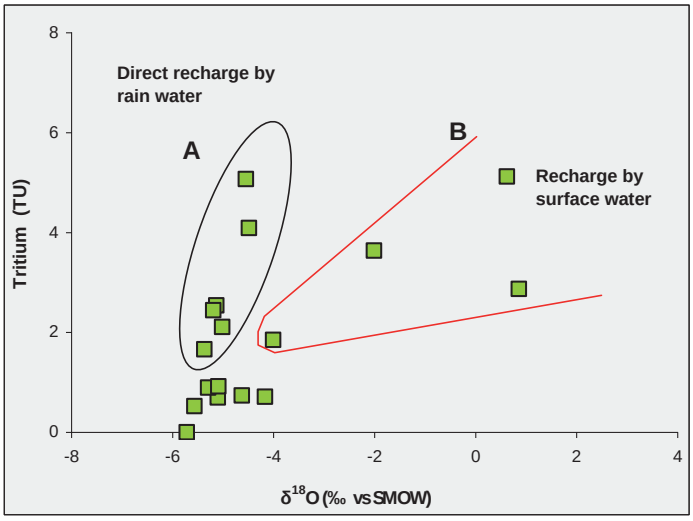
Since January 2008, surface and groundwater samples have been collected from more than 100 sampling points in the study area, including 13 surface water samples from lakes and rivers, 22 shallow groundwater samples, and 65 deep groundwater samples in the Trarza basin (figure left). Surface water samples showed a stable water isotope slope ($\delta^2H/\delta^{18}O$) of 5.2, below the Global Meteoric Water Line (GMWL). These results, as well as a positive correlation between the values of TDS and ^{18}O, suggest evaporation effects. The tritium values in surface water (1.81 to 5.23 TU; mean: 3.20 TU) were lower near the coast, possibly due to the influence of water from the Atlantic Ocean, which is also suggested by hydrochemical analysis (e.g., sodium chloride water type and high salinity for samples near the coast).

For shallow groundwater, the analysis of $\delta^{18}O$ and δ^2H suggests that there are two groups: one group found slightly below the GMWL (Group A), and the other overlapping the stable water isotope values of surface water (Group B) (see figures next page). The plot of ^3H vs $\delta^{18}O$ also suggests the presence of these two groups. The similarity of stable water isotope values of Group B to those of surface water may be due to the infiltration of river and lake waters which underwent evaporation, while the contribution of direct rainwater recharge is suggested for Group A.

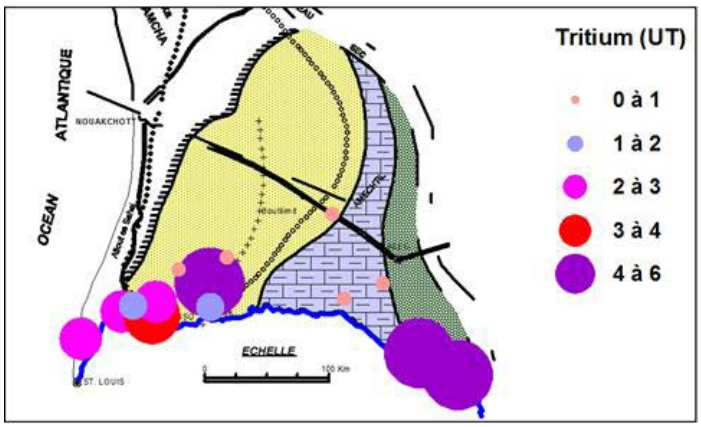
Deep groundwater

In deep groundwater, many water samples show similar stable isotope and tritium contents. These stable isotope values are isotopically more negative and found to be on or slightly below the GMWL. Tritium values are also low (0–1.97 TU), suggesting direct infiltration of relatively recent rain water. A few exceptions involving higher stable water isotopes and tritium values included samples collected near the river and at the Aleg Lake 1 station, suggesting the contribution of river and lake waters which were subject to evaporation. Carbon-14 analysis is expected to further examine the recharge pattern of groundwater, including evaluation of the possible direct recharge of rain water. Although water quality was satisfactory in many samples, based on the results of hydrochemical analysis, several samples had very high nitrate values (80–200 mg/L) and high salinity (up to 1 g/L). More intensive studies of these samples are also expected to suggest their possible water sources. This isotope hydrology project has begun to reveal the characteristics of aquifers in this region by showing spatial differences in each layer, differences between shallow and deep layers, and interactions with river and ocean waters, with the goal of providing information for a safe drinking water supply.





Analysis of $\delta^{18}O$ and $\delta^{2}H$ suggests there are two groups: one group found slightly below the GMWL (Group A), and the other overlapping the stable water isotope values of surface water (Group B).



Results of tritium analysis.

Reference:

FAO. Water Resources, Development and Management Service. 2002. AQUASTAT.

For further information contact M. Ito at M.Ito@iaea.org

Note

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Contributions to the newsletter are welcome.

News in Brief

New Staff Members

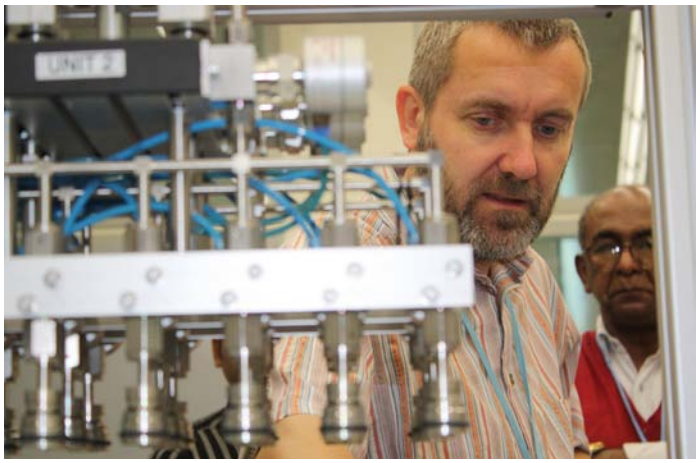
• Mr. Takuya Matsumoto joined the Isotope Hydrology Section as Isotope Analyst in November 2010. Mr. Matsumoto was previously an Associate Professor at the Institute for Study of the Earth's Interior of Okayama University in Japan. He has conducted research on the geochemistry of terrestrial and extra-terrestrial materials applying isotope techniques to investigate the evolution of the planets, including the Earth, and to examine the global scale material cycling from the Earth's surface to deep interior. He has also developed equipment to obtain high quality isotope data from samples in different forms (including various rocks, minerals, gases and waters). In the Section, he will be responsible for the mass spectroscopic analysis of noble gas isotopes in groundwater samples primarily to obtain precise information on the age and recharge temperature of groundwater, and work as Co-Project Officer for the Coordinated Research Projects on Estimation of Groundwater Recharge and Discharge by Using the Tritium-Helium-3 Dating Technique.

• Mr. Naoyuki Kurita joined the Isotope Hydrology Section as a consultant in January 2011. Mr. Kurita is on leave one year from Japan Agency for Marine-Earth Science and Technology (JAMSTEC), where he is a research scientist. He has a background in atmospheric science. As his current research activity, he manages daily basis Asian precipitation sampling network and Oceanic water vapor sampling program for isotope analysis and evaluates observed isotope data by using global climate model incorporated water isotopologues. While he is in the IHS, Mr Kurita's activity will include evaluation of Agency's archived water isotope data by using isotope incorporated model and feedback to the Agency's isotope monitoring network activity.

Departing Staff Members

• Manfred Groening joined the IAEA in Oct 1995 as Unit Head of the Isotope Hydrology Laboratory, with a background in environmental physics (noble gases/ paleatemperature studies in groundwater). He left this position in December 2010 to move to the Terrestrial Environment Laboratory in Seibersdorf, where he is responsible for all IAEA stable isotope reference material activities and setting up there a new stable isotope laboratory dedicated for reference material calibration work.

During his 15 years at the IHL, some of the milestones achieved during his tenure include: Establishment of a CFC laboratory for groundwater dating (1996); establishment of the noble gas laboratory for T/^{3}He dating (2002-2010); space extension of the IHL through doubling of the available space to 800 square meters; focus to improve calibration and quality assurance for laboratories; extensive work on reference materials and interlaboratory comparisons; and development/improvement of sampling/analysis techniques, and the routine operation of the laboratory for providing analysis for isotope monitoring networks and technical cooperation projects.



Manfred Groening, former laboratory head, has moved to Seibersdorf to take up a new post.

In 2005 Mr. Groening was honored to be elected as a Member of the Commission of Isotopic Abundances and Atomic Weights (CIAAW) of the IUPAC (he is still there as one of six Titular Members), dealing with high precision isotopic abundance measurements for all elements and the related atomic weights of the elements.

• Axel Suckow left the Agency in September 2010 after completing his seven year tenure. During this time, Mr. Suckow installed the noble gas facility in the Isotope Hydrology Laboratory. The facility is intended to age date natural lake, marine or groundwater using the combination of tritium/^{3}He, estimate the age of old (<1000 years to millions of years) groundwater, quanitifying the amount of ^{4}He in groundwater, and reconstuct the infiltration conditions (temperature, altitute and salinity) of groundwater using concentrations of neon, argon, krypton and xenon.

Axel Suckow installed the noble gas facility in the Isotope Hydrology Laboratory.

During the installation

of this machine, several new techniques were tested and installed routinely which are new in noble gas laboratories worldwide, including: the possibility to automatically split large amounts of helium from solubility equilibrium up to one million times this value; making possible the splitting of helium up to a factor of 10 000 above solubility equilibrium without influencing the neon result in a measurable way; introduction of collet-chuck connectors allowing an offline gas extraction system with all metal gas and ingrowth-bulbs; refinement of a series of temperature controllable cryo-traps working with either charcoal or 'naked' steel allowing quick separation of heavy noble gasses from each other; a fully scalable skript language controlling the measurement process with elements of high level procedural programming languages, allowing for the parallel processing of many command queues; this allowed use of coupled system with four mass spectrometers simultaneously; and this in turn allowed an unprecented throughput for measurements of all noble gases in groundwater samples.

Mr. Suckow also installed a new database and laboratory management system for the isotope hydrology laboraty, which now runs all data produced there. As well, he contributed a chapter to the guidebook on dating old groundwater, and edited the entire book, which is now on its way to the next step in the publishing procedure.

• Mr. Tomas Vitvar, Isotope Hydrologist, worked in the Isotope Hydrology Section from September 2003 to September 2011. Mr. Vitvar worked as Technical Officer for a number of national and regional Technical Cooperation projects in isotope hydrology in Latin America, Africa, Europe (Caucasus) and Asia, helping the counterparts in communication with his multilingual skills in Spanish, French and Russian, in addition to English. He also worked as Scientific Secretary for the Coordinated Research Projects on Design Criteria for a Network to Monitor Isotope Compositions of Runoff in Large Rivers and Isotopic Age and Composition of Streamflow as Indicators of Groundwater Sustainability. He helped in the launch of other CRPs, including Isotopic Techniques for Assessment of Hydrological Processes in Wetlands and Use of Environmental Isotopes in Assessing Water Resources in Snow, Glacier, and Permafrost Dominated Areas under Changing Climatic Conditions. He chaired an EGU session in 2005 and co-organized in cooperation with International Commission for the Protection of the Danube River and Austrian authorities the isotope sampling and analysis programme of the Joint Danube Survey 2. Global Network in Rivers (GNIR), a global database of isotope data of river waters, was established through the work on the CRP on Isotopic Age and Composition of Streamflow as Indicators of Groundwater Sustainability. He encouraged the counterparts and guided their participation in the GNIP and GNIR and contributed to the growth of these database programmes.

Obituary

• One of the most important and most influential scientists to use stable isotopes in the study of the natural water cycle, Dr. Willi Dansgaard (Copenhagen 1922-2011), died on January 8. Dr Dansgaard was a Professor of Geophysics, from 1992 Professor Emeritus, at the University of Copenhagen. In particular, he should be considered the founder of isotope glaciology.

One of the most important and most influential scientists to use stable isotopes in the study of the natural water cycle, Dr. Willi Dansgaard, has died.

Dansgaard had a long history of collaboration with the Isotope Hydrology Section of the IAEA, the programme of which he helped to formulate. He was the first to scientifically exploit data on the stable isotope composition of precipitation from GNIP — the worldwide network of stations established by the IAEA and WMO in around 1957. The most important and known product of this interest was his classical paper Stable Isotopes in Precipitation, published in 1964 in Tellus, one of the most quoted on the whole history of isotope hydrology.

Subsequently, his scientific interests turned almost exclusively to glaciology and paleoclimatology, i.e. to the detailed reconstruction of climate during the Holocene and the late Pleistocene, recorded by the stable isotope composition of polar ice — a field in which he rapidly became a recognized authority. Together with Hans Oeschger (1927–1998), he discovered the climate fluctuations which occurred during the last glaciation; these were named Dasngaard-Oeschger events.

Dansgaard participated in several expeditions to Greenland to collect ice cores from deep drilling, the techniques of which were continuously refined. He described his research and life experience in polar regions in the booklet Frozen Annals. Greenland Ice Sheet Research, published by the Niels Bohr Institutet, University of Copenhagen, in 2004.

• Edward Bradley, an American former colleague in the Isotope Hydrology Section of the IAEA, passed away on 14 November 2010. Bradley, born in February 1922, was a career groundwater geologist. He spent the years 1969-1972 serving as a hydrogeoogist at the IAEA, and worked for the US Geological Survey (USGS) from 1950-1979, with assignments in several parts of the US. He also travelled overseas to advise on groundwater in several countries.

The Beginnings of Isotope Hydrology in Italy: The Pisa Nuclear Geology Laboratory

By R. Gonfiantini, Institute of Geosciences and Georesources, Pisa, Italy

The Water Resources Programme hopes to capture some of the memories of isotope hydrology's early pioneers in an attempt to hang on to important historical developments of this young science and convey the excitement of that time. Articles from other forerunners in this field will appear from time to time in the section's newsletter.

The author, Roberto Gonfiantini.

After 24 years of work with the International Atomic Energy Agency in Vienna, and subsequent peregrinations to the Institute of Reference Materials and Measurements of the European Union in Geel, Belgium, and the Laboratory of Hydrology and Isotope Geochemistry of the University of Paris-Sud (Orsay), the author of this article returned to Pisa in 1997 to direct the Institute of Geochronology and Isotope Geochemistry. He is now associated scientist of the Institute of Geosciences and Georesources of the National Research Council of Italy. He sketches here the history of the Nuclear Geology Laboratory of Pisa University, where he was working for eleven years at the beginning of his scientific career.

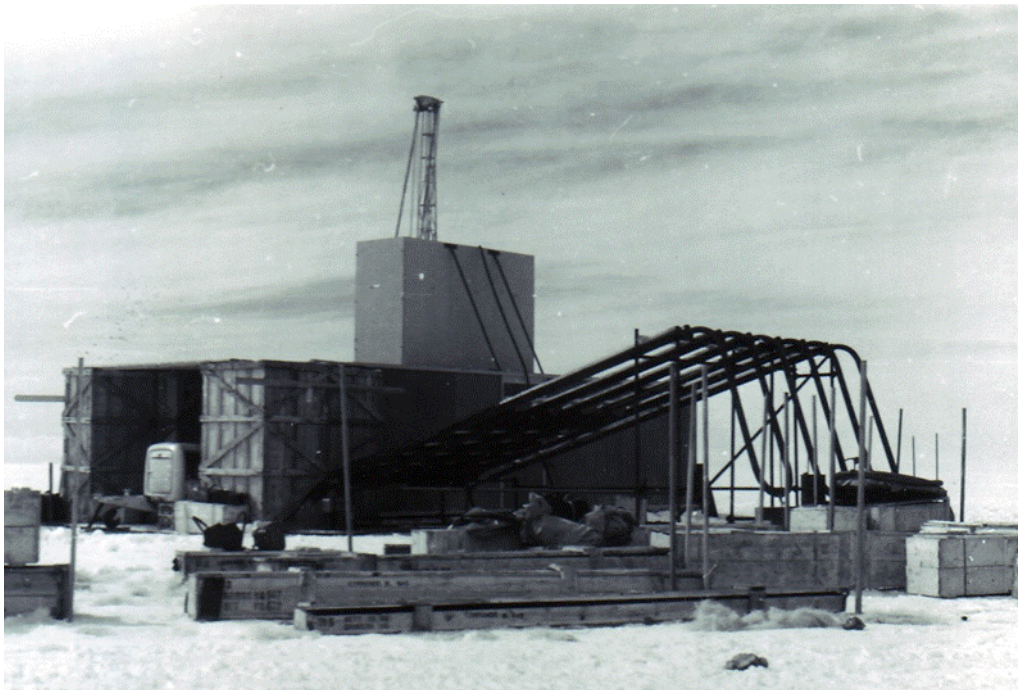
Five days after my graduation in chemistry in 1958, I started working at the Nuclear Geology Laboratory of the Pisa University and saw a mass spectrometer for the first time in my life. It was a gas mass spectrometer with a double viscous-flow inlet system and double collector, 60°-magnetic sector, constructed after Nier's design (Nier, 1947) by Prof. Giovanni Boato at Genoa University. Boato had spent a period with Harold Urey and his group of young isotope geochemists at the University of Chicago — a group which included scientists such as Harmon Craig, Sam Epstein, Jerry Wasserburg, Irving Friedman and others. Urey and his group were the founders of modern isotope geochemistry.

The mass spectrometer had rather rudimentary elements, typical of homemade instruments, but it was capable of high quality performance: for instance, the routine measurement uncertainty on $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratio variation determinations was only 0.1‰, not far from those of modern machines, and sufficient for most geochemical investigations. The instrument, and in particular its tube electronics, were sensitive to electric net voltage variations and room temperature changes, so I preferred to perform my measurements during the night, when the net was more stable and nobody was around to enter the room. I still remember the pleasure of emerging from the lab and walking in the old streets of Pisa in the early morning light.

Pisa Nuclear Geology Laboratory

The Pisa Nuclear Geology Laboratory was created in the mid-1950s by Prof. Ezio Tongiorgi (Milan, 1912–Pisa, 1987), and was the first in Italy and among the first in Europe to apply isotope and nuclear techniques in geology. Tongiorgi had in fact had early intuition about the role nuclear and isotopic techniques were going to play in Earth sciences. He was an eclectic scientist with manifold interests and experiences in geology, botany, palaeontology, archaeology, old Pisan pottery, old books (his home was literally full of thousands of books), some of which he was cultivating together with his wife Liana. He was a Renaissance man.

The main techniques available in the laboratory at the time



Princess Raghnild Coast, Antarctica, January 1961, with an ice drill at the Belgian King Baudouin Station (70°26'S-24°19'E). In three weeks, a continuous ice core was collected up to a depth of 115 m. The operation was cosponsored by the Université Libre de Bruxelles and the Nuclear Geology Laboratory of Pisa University.

of my engagement were carbon-14 dating of archaeological samples using low level counting (the counting gas was acetylene), with pleochroic halos and thermolumiscence as rock dating tools. Shortly after, Rb-Sr and K-Ar rock dating techniques were added to the laboratory equipment. Among my colleagues at that time, I would like to mention Giorgio Ferrara, Antonio Longinelli, Giuseppina Fornaca-Rinaldi and Max Reinharz. The last was a Viennese physicist who adventurously ended up in Italy during WWII: he was a Jew who had escaped the Holocaust (though his parents did not), and had gone up the peninsula fighting in the British Army. He taught me the fundamentals of mass spectrometry and helped in my initial moves in science. Suddenly, some months later, he was declared an undesirable person — he was politically left in the times of cold war, and thus obliged to leave Italy. Max first joined the Institute of Physics at Bern University and then CERN in Geneva.

Gas mass spectrometer

The gas mass spectrometer was initially intended for palaeotemperature determinations through oxygen stable isotope ratios of shell calcium carbonate, the measurement technique of which I was in charge of setting up. Pretty soon, however, I had to turn to oxygen isotopic analyses in water, because I was asked to determine the $^{18}O/^{16}O$ variations in precipitation samples collected by Prof. Edgar Picciotto at the Free University of Brussels, during the one year spent at the Belgian Antarctic Base in Queen Maud Land. Results showed large seasonal isotopic variations of precipitation (Gonfiantini and Picciotto, 1959), which is the basis for dating, estimating accumulation rates, and reconstructing past climatic changes along snow and firn vertical profiles, as first suggested by Epstein (1956). From that time on, however, natural waters became a major field of investigation using isotope techniques in the Pisa laboratory. A couple of years later, a new Varian Mat mass spectrometer manufactured by Atlas Werke in Bremen was acquired for measuring $^{2}H/^{1}H$ ratio variations, for which the Boato mass spectrometer was not suitable.

In those early times of isotope hydrology, available data were still scarce and the scientific farmework very incomplete, and it was relatively easy... to discover new effects and achieve new findings.

In those early times of isotope hydrology, available data were still scarce and the scientific framework very incomplete, and it was relatively easy, with a bit of scientific curiosity and imagination, to discover new effects and achieve new findings. Some of the first studies which we performed are listed below.

1. The study of Lake Bracciano: a quasi-closed volcanic lake on the north of Rome, showed that the isotopic composition of lake water — fully fresh — was close to that of ocean water. This is a consequence of lake water balance, in which evaporation compensates almost entirely the fresh water inflow from precipitation and runoff (Gonfiantini et al., 1962). The study demonstrated that shallow groundwater is not significantly recharged by the lake, in contrast to what some hydrogeologists believed. As a curiosity, forty years later, the water of Lake Bracciano, because of its isotopic composition, was chosen as the starting material for preparing the reference water VSMOW-2 at the IAEA.

2. The weekly monitoring of three rivers in Tuscany showed

for the first time that important isotopic variations can be induced in rivers by intense precipitation (Gonfiantini et al., 1963). This observation contained the embryo for the basis of isotopic hydrograph separation, as it was later proposed (e.g. Fritz et al., 1976).

3. The isotopic composition of salt water in evaporation experiments under controlled conditions showed for the first time the hook trend in a $\delta^{18}O$–$\delta^{2}H$ diagram (Gonfiantini, 1965a; Fontes and Gonfiantini, 1967). The trend is due to isotopic fractionation in water bound in the hydration sphere of ions (first discovered by Taube, 1954) combined with increasing salinity. Later, this subject was fully elaborated by Sofer and Gat (1972).

4. The first investigation on the isotopic composition of water in leaves showed that heavy isotope enrichment occurred, with a maximum in the early afternoon and minimum in the early morning following relative humidity changes in the air (Gonfiantini et al., 1965). This study was suggested and fostered by Prof. Tongiorgi — originally a naturalist — and it opened a new field of investigation: isotope applications in plant physiology. Other fields of investigation directly related to the isotopic composition of leaf water, which started shortly after, include isotope applications to palaeoclimatogy based on plant isotopic composition, and food adulteration.

5. Investigations into Antarctic ice continued. In January 1961 I took part in the Belgian summer expedition to Antarctica, during which a 115 m drill procedure was undertaken, with complete recovery of the ice core. Stable isotope measurements were carried out in Pisa, but the results were only published in part (Gonfiantini et al., 1963; Gonfiantini, 1965b).

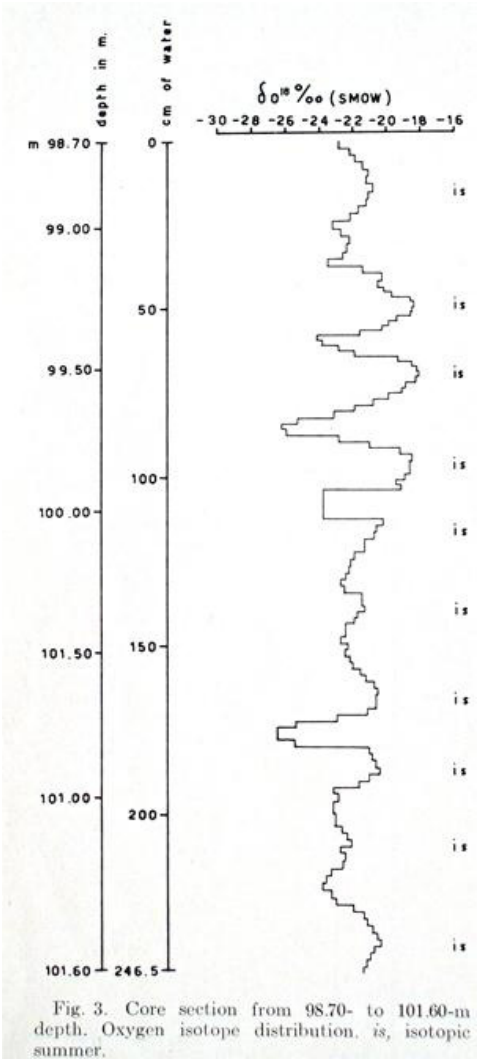


Fig. 3. Core section from 98.70- to 101.60-m depth. Oxygen isotope distribution. *is*, isotopic summer.

Isotope stratigraphy in the ice core from the drilling at King Baudouin Station, Antarctica. The ice core depth is 98.70 to 101.60 m. The seasonal variations are still preserved (is = isotopic summer) in spite of compaction. The snow of this core section was deposited around the middle of the XIX century, i.e. towards the end of the 'little ice age': the mean oxygen-18 content is 1.2 ‰ lower than in surface snow, indicating cooler conditions at the time of deposition. (From Gonfiantini, 1965).

6. Isotopic investigations into the geothermal field of Larderello indicated the meteoric origin of hot steam — a notion which is nowadays trivial but which was not yet generally accepted at that time (Ferrara et al., 1965). Later, with acquisition of the tritium measurement technique, it was possible to demonstrate that geothermal waters were older than 30 years, i.e. pre-thermonuclear (Panichi et al., 1974). Geothermal investigations received great momentum in the subsequent decade, especially through Costanzo Panichi and Franco D'Amore.

Harmon Craig

In 1964, Harmon Craig from the Scripps Institution of Oceanography, San Diego, spent a sabbatical year at our laboratory in Pisa, and the daily contact and discussions with him were enormously fruitful for us young scientists and beginners in the field of stable isotope geochemistry. At that time, in fact, it was not easy to obtain financial support for long stays in foreign institutes. He always remained a good friend of our laboratory. During his stay in Pisa, Craig developed most of his evaporation model and associated isotopic effects, destined to become a milestone in isotope hydrology (Craig and Gordon, 1965).

In January 1970, I moved to Vienna to join the IAEA Section of Isotope Hydrology, directed by Brian R. Payne, where I remained until 1993. In Pisa, work in isotope hydrology was continued, especially through Costanzo Panichi and Antonio Longinelli. The latter added to the available techniques the determination of isotopic composition of oxygen and sulphur of sulphate dissolved in natural waters. This technique was developed by him during a stay in Craig's laboratory in La Jolla (Longinelli and Craig, 1967). After his return to Pisa, together with Gianni Cortecci, he applied this technique to investigate the origin of sulphate contamination in rivers (Longinelli and Cortecci, 1970); this was one of the first studies of this type in the world.

During the 1960s, isotope applications in hydrology put down solid roots in Pisa. The Nuclear Geology Laboratory had become one of the most important centres for isotope hydrology, with frequent visitors from all over the world. A few names worth mentioning include (I cite here only those related to the isotopes of light elements): Jean-Charles Fontes and Peter Fritz, who spent about two years in Pisa and went on to become well known isotope hydrologists and institute leaders, Jean-Charles in Paris (Orsay) and Peter

Glaciological pit at the King Baudouin Station, Antarctica. Preparation of the ice cores for shipment to Europe.

in Canada and Germany[1]. Then Mike Stewart (Lower Hutt, New Zealand), Henry Schwarcz (MacMaster, Canada), Liviu Blaga (Cluj, Rumenia), Colette Grazzini (Paris), and of course Harmon Craig, who remained several months to work with us. I also remember short, often repeated, visits by Cesare Emiliani (Miami), Joel Gat (Rehovot), Hans Oeschger (Bern), René Létolle (Paris), Sam Epstein and Roberto Clayton (Chicago), Umberto Colombo and Franco Gazzarrini (Donegani Research Institute, Novara), Admar Cervellini and Eneas Salati (CENA, Piracicaba, Brazil), and many others.

Exciting visitors

Particularly exciting were the visits of exceptional scientific personalities such as Harold Urey, Nobel laureate for the discovery of deuterium, Robert Oppenheimer, who directed the Manhattan Project for the construction of the first atomic bombs during the Second World War, Fritz Houtermans and Edgard Picciotto. The last two were customary visitors and sort of permanent advisers to our laboratory. Houtermans was a physicist who ended up in Bern to direct the Institute of Physics after an adventurous scientific itinerary across laboratories in England, Russia and Germany. He was the first to explain, together with Robert Atkinson, star energy production through thermonuclear reactions (the fusion of hydrogen nuclei to form helium). According to his friend George Gamow, Houtermans used to work in cafés "as all Viennese do". Picciotto was a geochemist at the Nuclear Physics Laboratory of the Free University of Brussels, specialized in polar ice geochemistry, and an organiser and participant of the Belgian Antarctic expeditions. Both were high calibre scientists.

Houtermans, Picciotto and Tongiorgi organised a course on nuclear geology in the summer of 1960, which took place in Varenna on Como Lake. Several well known specialists made presentations: in particular for isotope hydrology and related fields this included Fritz Begemann, Giovanni Boato, Robert Clayton, Willi Dansgaard, Sam Epstein, Charles Keeling, Karl-Otto Münnich, Etienne Roth, Hans Suess and John Vogel, all people who left behind a vast legacy of ideas and data, and who have educated a large number of isotope geochemists. The proceedings of the course (Houtermans et al., 1961) remained a useful reference text for years.

In the years subsequent to 1970, the Pisa Nuclear Geology Laboratory went through several changes and transformations, but research in isotope geochemistry and hydrology continued to be pursued. Antonio Longinelli and Gianni Cortecci left the institute in the early 1970s to

1 In October 1993, Jean-Charles Fontes succeeded me as Head of the IAEA Section of Isotope Hydrology. He died four months later in a car accident during a field mission to Mali.

Nuclear Geology Laboratory of Pisa University (around 1965), with a gas isotopic ratio mass spectrometer, manufactured by Atlas Werke, Bremen. The machine had a 180° magnetic sector and a double, manually operated, viscous flow inlet system (photo credit: Photographic Archives of University of Pisa).

Ezio Tongiorgi (Milan 1912-Pisa 1987). Prof. Tongiorgi established the Nuclear Geology Laboratory of Pisa University in 1956.

teach isotope geochemistry and create new laboratories in other Italian universities: Longinelli in restless succession to Palermo, Trieste and Parma, and Cortecci to Bologna. Eventually, in the 1970s the Nuclear Geology Laboratory split into two parts: the first constituted the backbone of the International Institute of Geothermal Investigations — where isotope techniques continued to be applied in hydrology, with emphasis on hydrothermal systems, especially by Costanzo Panichi and Franco D'Amore — and the second generated the Institute of Geochronology and Isotope Geochemistry under the leadership of Giorgio Ferrara.

Ten years ago the two above institutes merged to form, together with other smaller research centres, the Institute of Geosciences and Georesources (IGG), in a sort of return to origins — so complicated are the fortunes of Italian scientific institutions. The IGG is hosted in the new science compound (Area della Ricerca) created in Pisa by the National Research Council of Italy and assures — so to say — scientific continuity with the former Nuclear Geology Laboratory.

References

CRAIG, H. (1965). The measurement of oxygen isotope paleotemperatures. In: Stable Isotopes in Oceanographic Studies and Paleotemperatures (TONGIORGI, E., Ed.), pp. 3-24. CNR-Laboratorio di Geologia Nucleare, Pisa.

EPSTEIN, S. (1956). Variation of the 18O/16O ratio of fresh water and ice. Natl. Acad. Sci. Natl. Res. Council Public., 400, 20-28.

FERRARA, G.C., GONFIANTINI, R., PANICHI C. (1965). La composizione isotopica del vapore di alcuni soffioni di Larderello e dell'acqua dialcune sorgenti e mofete della Toscana (The isotopic composition of some geysers of Larderello and of some springs and mofettes of Tuscany), Atti Soc. Toscana Scienze Nat., A, 72, 570-588.

FONTES, J-Ch., GONFIANTINI, R. (1967). Comportement isotopique au cours de l'évaporation de deux bassins sahariens. (Isotopic behaviour of two Saharian ponds during evaporation), Earth Plan. Sci. Letters, 3, 258-266 and 386 (errata).

FRITZ, P., CHERRY, J.A., WEYER, K.U., SKLASH, M. (1976). Storm runoff analysis using environmental isotopes and major ions. In: Interpretation of Environmental Isotope and Hydrochemical Data in Groundwater Hydrology, IAEA, Vienna, 111-130.

GONFIANTINI, R. (1965a). Effetti isotopici nell'evaporazione di acque salate (Isotopic effects in salt water evaporation), Atti Soc. Toscana Scienze Nat., Serie A, 72, 550-569.

GONFIANTINI, R. (1965b). Some results on oxygen isotope stratigraphy in the deep drilling at King Baudouin Station, Antarctica, J. Geophys. Res., 70, 1815-1819.

GONFIANTINI, R., GRATZIU, S., TONGIORGI, E. (1965). Oxygen isotopic composition of water in leaves. In: Isotopes and Radiation in Soil-plant Nutrition Studies, IAEA, Vienna, 405-410.

GONFIANTINI, R., PICCIOTTO, E. (1959). Oxygen isotope variations in Antarctic snow samples. Nature, 184, 1557-1558.

GONFIANTINI, R., TOGLIATTI, V., TONGIORGI, E. (1962). Il rapporto 18O/16O nell'acqua del Lago di Bracciano e delle falde a sud-est del lago (The 18O/16O ratio in the water of Lake Bracciano and in groundwater south-east of the lake). Notiziario CNEN, 8 (no. 6) 3-9.

GONFIANTINI, R., TOGLIATTI, V., TONGIORGI, E. (1963). Some possible applications of isotopic analysis of water to hydrologic problems. In : Science et techniquepour les régions peu développées (Italian Reports to the U.N. Conference, Geneva 1963), CNR Roma, pp. 71-

GONFIANTINI, R., TOGLIATTI, V., TONGIORGI, E., De BREUCK, W., PICCIOTTO, E. (1963). Snow stratigraphy and oxygen isotope variations in the glaciological pit of King Baudouin Station, Queen Maud Land, Antarctica. J. Gephys. Res., 68, 3791-3798.

HOUTERMANS, F.G., PICCIOTTO, E.E., TONGIORGI, E. (Directors) (1961). Summer Course on Nuclear Geology, Varenna, Italy, 1960. Comitato Nazionale per l'Energia Nucleare, V. Lischi, Pisa (1961) 429 p.

LONGINELLI, A., CORTECCI, G. (1970). Isotopic abundance of oxygen and sulfur in sulfate ions from river water. Earth Planet. Sci. Letters, 7, 376-380.

LONGINELLI, A., CRAIG, H. (1967). Oxygen-18 variations in sulphate ions in sea water and saline lakes, Science, 156, 56-59.

NIER, A.O. (1947) A mass spectrometer for isotope and gas analysis. Review Sci. Instrum., 18, No. 6, 398-411.

PANICHI, C., CELATI, R., NOTO, P., SQUARCI, P., TAFFI, L., TONGIORGI, E. (1974). Oxygen and hydrogen isotope studies of the Larderello (Italy) geothermal system. In: Isotope Techniques in Groundwater Hydrology, Vol. II, IAEA, Vienna, 9-28.

SOFER, Z., GAT, J.R. (1972). Activities and concentrations of oxygen-18 in aqueous salt solutions: analytical and geophysical implications. Earth Plan. Sci. Letters, 15, 232-238.

TAUBE, H. (1954). Use of oxygen isotope effects in the study of hydration of ions, J. Phys. Chem., 58, 523-528.

Meetings in 2011

- International Symposium on Isotopes in Hydrology, Marine Ecosystems, and Climate Change Studies, Monaco, 27 March–1 April.
- Technical Meeting on Integration of Isotope Data in Rainfall-Runoff Models for Characterizing Watershed Hydrology, Vienna, Austria, 16–20 May.
- Technical Meeting on Laser Based Stable Isotope Analysis Users Group Meeting, Vienna, Austria, 9–11 November.
- 2nd Research Coordination Meeting on Use of Environmental Tracer Techniques to Improve Basin-Scale Recharge Estimation, Vienna, Austria, 5–9 December.

Upcoming compilation

The Water Resources Programme is creating a compilation of the most relevant IAEA publications in the field of isotope hydrology and related disciplines in the form of pdf files. These are already largely accessible through our webpage (www.iaea.org/water), and the Section is planning to make the documents available on DVD. These materials have been published by the IAEA over a period spanning almost 50 years (1962–2010). Most IAEA Water Resources programme publications are now out of print, although they are often cited in scientific literature. This compilation is expected to provide easier access to key publications in the field. The material has been grouped into five categories:

- Proceedings of IAEA symposia in the fields of isotope hydrology and water resources management (13), environmental change (3), and selected early symposia on soil–plant studies (2);
- Monographs and guidebooks describing isotope and related techniques and methodologies as well as publications presenting isotope data collected as part of global monitoring programmes;
- Technical documents (IAEA-TECDOCS) describing the results of isotope studies carried out as part of Coordinated Research Projects (CRPs) and Technical Cooperation (TC) projects;
- Atlases recently produced by the IAEA presenting isotope data and related hydrological information compiled from previous isotope hydrology studies conducted with the assistance/sponsorship of the IAEA;
- Training material distributed to teach isotope hydrology in various languages.

This compilation provides a comprehensive chronicle of the development of isotope hydrology as a scientific discipline and contains some of the key seminal papers in the field. These materials are also available at the IAEA web page: www.iaea.org/water

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