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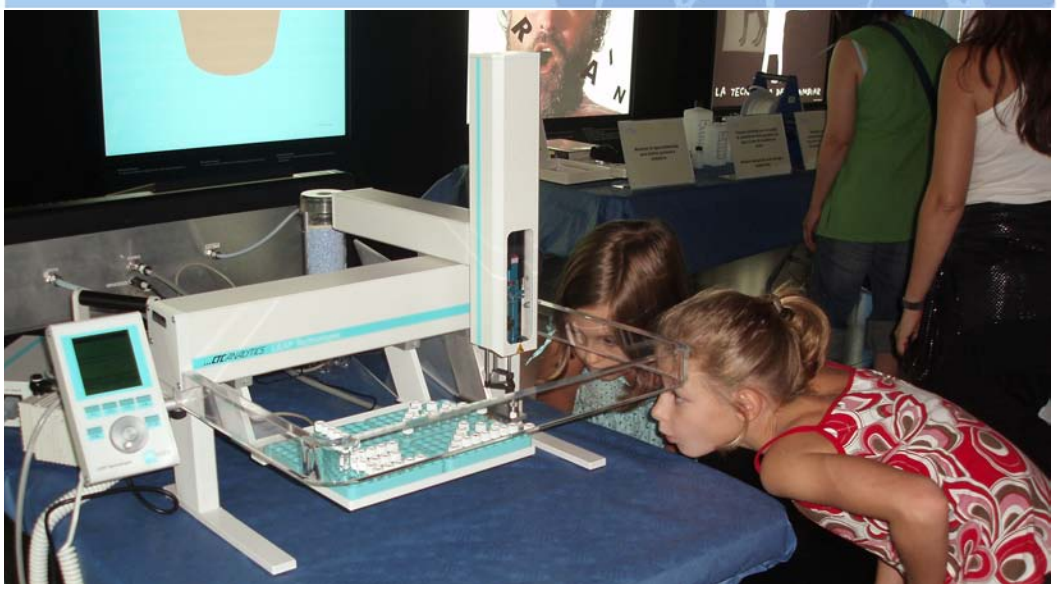
In this Issue

IAEA Water Resources Programme



Two curious children examine equipment from the Water Resources Programme, on display at the Zaragoza Expo on the 28–29 August in Zaragoza, Spain. (Photo Credit: T.Kurttas/IAEA).

From the Section Head

The Isotope Hydrology Section has made great leaps throughout 2008 in getting information to the public and experts, where it can truly make a difference. From promotion of the section and its activities at the Water Expo in Zaragoza, Spain in August, to the release of a follow-up Atlas of Isotope Hydrology for Asia and the Pacific in September, and the printing and release of a technical document and a French publication in November, word is being spread about the use of isotopes in managing water resources. For the first time, the section produced a film – 'Search for Water' – which was released in August to coincide with the Zaragoza Expo, where it had its first public screening. Graphics and voiceover successfully lead the viewer through the story of isotope hydrology and into the basic details of how it functions and what the science is capable of. Over 15 000 interested visitors came through the IAEA's display at the Zaragoza Expo, which was highly rated by both organizers and viewers alike. Along with the film, the exhibition included displays, posters and other reading material. The Atlas of Isotope Hydrology for Asia and the Pacific follows on the heels of the first atlas released by the section in August 2007 on Africa. Easy-to-follow illustrations present nearly 16 000 isotope records from 105 projects active between 1973 and 2007 in 16 Member States. The next in the planned series – on Latin American countries – is already in progress. Ongoing data gathering and mapping activities in the isotope hydrology section – which include compilation of values and digitizing of data – are the basis of information dissemination through projects like the atlases, internet programs such as WISER, and for the preliminary evaluation of data interpolation methods and algorhythms.

Pradeep Aggarwal

Water, Water Everywhere...

The Isotope Hydrology Section produced a multi-faceted, multi-media exhibition for the Zaragoza Water Expo2008, which brought the story of water and isotopes to masses of people.

(Photo Credit: T.Kurttas/IAEA).

When you turn on your tap in the kitchen for a glass of water or to have a shower, when you start your dishwasher or washing machine, do you think about where the water you are using comes from?

If your answer is no, you are in the same category as most people on this planet. Water awareness is an issue that must be addressed, but sadly so infrequently receives public attention or thought. That is why the isotope hydrology section made an extra effort to bring fore the IAEA's role in the world of water at a recent Expo in Zaragoza, Spain, and raise public awareness to try and preserve our planet's precious water resources.

Two members of the IAEA's Water Resources Programme - Luis Araguás-Araguás and Türker Kurttas - spent 28–29 August in Zaragoza, Spain at Expo2008 explaining an exhibition in which water was the star. Over 15 500 people came to the UN Water Pavilion over those two days, where the story of isotope hydrology was told using a multi-media approach. Other IAEA contributors to the display included the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, the Department of Technical Cooperation, and the Planning and the Economic Studies Section, of the Department of Nuclear Energy, which supplied both posters and handouts.

The Expo, which ran between June 14 and September 14, was held under the theme 'Water and sustainable development' and included participation from more than 130 countries, territories, international agencies, commercial companies and NGOs. According to organizers, there were 10 thematic weeks held, featuring more than 400 speakers and 2 000 experts. Participants got their word across to the 5.6 million visitors over the three months using exhibitions, displays, films and thematic conferences in the various pavilions.

The IAEA's contribution was highly rated by organizers, and there was often a queue to see the many activities on display by the isotope hydrology section, including a new, 10-minute film explaining isotope hydrology from a layman's perspective, complete with a graphic breakdown of how isotopes function and the role they play in mapping water to aid in appropriate planning and use of this precious resource. The film was projected several times over the two days, along with other films provided by different UN agencies.

The exhibit also included an aquifer model representing a cross-section of a borehole filled with water and accompanied by commonly used field and laboratory equipment, a recently developed liquid-water stable isotope analyser machine for measuring the oxygen-18 and deuterium content of water samples, and an exhibition of groundwater samples of differing ages. The bottled collection from the Great Artesian Basin, Australia (110 000 to 120 000 years old), the Kufra basin, Libyan Arab Jamahiriya (20 000 to 25 000 years old) and from a karst aquifer in Austria (about 5 years old), was meant to explain to visitors the different characteristics of water from varying sources and clarify how groundwater age provides information for sustainable use of water assets. There were also 12 new posters, as well as bookmarks and post cards, and folders were available containing various pamphlets

and leaflets compiled by the Water Resources Programme. "The overall balance of the IAEA display at Expo2008 was very positive, especially taking into consideration that it was addressed to an audience with limited knowledge of hydrology or nuclear techniques…." said Araguás-Araguás. "The aquifer model, the display with groundwater of various ages and the liquid-water stable isotope analyser called the immediate interest of most visitors and most questions were related to these items."

"The success of the exhibition can be assessed by the number of visitors inquiring for additional information on the presentation in the display area. The message on the need for a science-based approach to assess water resources was taken well by both those without previous knowledge of basic hydrology and isotope applications, as well as those with professional experience in environmental and related science," said Araguás-Araguás. "Some very positive comments were given to us, indicating, for example, that the display presented in the UN water pavilion was one of few really focussing on highly relevant water issues…"

The water tribune was set up at Expo Zaragoza 2008 as a space to reflect and discuss global water issues and sustainable development through innovation in the context of the 'Zaragoza method', or 'confronting matters through reflection'. Organizers of the Expo claim it was the largest-ever meeting about water, and added that through the tribune, 13 weeks of proposals and solutions were presented to confront the water crisis.

Director of the Tribune, Eduardo Mestre, stated concern over the risk that peace is at stake over the sharing of water, and added he is hopeful conflict over water can be avoided. He stated innovation and successful experience will be two points which can guide the world through the upcoming water crisis. Tribune talks are expected to lead to a 'Zaragoza Charter' – which Spanish Minister of the Environment and Rural and Marine Affairs Elena Espinosa hopes will become "a world reference in water affairs" - and a new (Water and Future) foundation, which aims to become a multi-disciplinary advisory office coordinated with the Secretariat of the United Nations Decade of Water. Organizers of the Zaragoza Expo have a vision to coordinate United Nations bodies addressing water problems at various levels into one organization based in Zaragoza, with the long-term goal being establishment of a permanent secretariat after 2015.

United Nations Secretary Ban Ki-moon stated at the Water Tribunal during his 1 September visit that, "We at the United Nations are strongly committed to protecting and properly managing the world's precious water resources. Providing access to safe drinking water and adequate sanitation are among the Millennium Development Goals agreed by United Nations Member States at the Millennium Summit in 2000…..We are encouraging Governments to use the Integrated Water Resources Management framework.

"There has been progress towards achieving the water and sanitation MDGs (Millennium Development Goals), but not enough. Since 1990, roughly 1.2 billion people have gained access to an improved source of drinking water. However, with rapid population growth and persistent poverty in parts of the developing world, the number of people without access has declined by only around 10 per cent. There are still more than one billion people lacking access to safe drinking water, and two-and-a-half billion lacking access to basic sanitation facilities….Multiple challenges remain.

"Expo Zaragoza is an important contribution that will help advance the world's efforts to provide safe drinking water and sanitation for all, and to manage the earth's water resources for the benefit of all the world's people, both now and in the future."

For further information please contact Luis Araguas at l.araguas@iaea.org

Isotope Hydrology Reaches the Public in Zaragoza

Search for Water

The Isotope Hydrology section has created for the first time a video aimed at explaining isotope hydrology to the greater public. This exciting, 10-minute video, produced by water expert Paul King and containing an interview with IAEA Director General Mohamed ElBaradei, sets the story of water to remarkable pictures from around the world, and the smooth tinkle of one of Earth's most modern instruments, the hang drum. Viewers learn about the fundamental water problems facing mankind today and in the future. Dr. ElBaradei discusses the IAEA's interest in isotopic water research and the goals of the agency in using these techniques. The basic concepts of isotope hydrology are explained using original graphic imagery, which includes a breakdown of water into heavy and light isotopic elements, clarifies how water can be traced to its sources and how its residence time under the earth can be determined. The practical use of isotopes in alleviating the looming water crisis is clearly laid out. Isotope hydrology is lauded as an inexpensive and effective tool which can be easily used to define water resources, including recharge capability, pinpoint pollutants, and even assess and mitigate climate change. The significance of water in our daily lives and the various roles it plays – from the very personal and emotional to its use in agriculture and industry – are eloquently displayed.

'Search for Water' was created for the Zaragoza Expo, held in Spain from June 14 and September 14, and had its first screening at the IAEA's exhibition at the Expo on 28–29 August. Visit http://www.iaea.org/water to see the video. ■

News in Brief

New Developments

- One of the priorities of the Isotope Hydrology Section is to place knowledge acquired on water resources at the disposal of all United Nations member states, including information arising from projects that have been financed by the IAEA for more than five decades. The region of Latin America now has its turn. In 2008, a review of information generated from more than one hundred projects in this zone began. More than 15 000 records on stable and radioactive isotopes taken from water samples in the area are to be counted and organized. This information will be published in an atlas, similar to the atlas of Africa produced last year by the section, and the Asia atlas, which is hot off the press. Through this project, Latin American countries will have a reference tool for future isotope hydrology projects, which can be either executed through outside initiatives or financed by the IAEA, in less than two years.

Conference

- Groundwater & Climate in Africa (http://www.gwclim.org), an international conference held in Kampala, Uganda from 24–28 June 2008, was a landmark. It was the first-ever meeting to discuss the role of groundwater in improving livelihoods in Africa under conditions of rapid development and climate change and one of the first conferences in the world to discuss the twin impacts of development and climate variability, as well as changes in groundwater resources and groundwater-based ecosystems. This impact remains poorly understood and is one of the most persistent knowledge gaps identified by the Inter-governmental Panel on Climate Change (IPCC) in both its 3rd (2001) and 4th (2007) Assessment Reports. Organized by the Ministry of Water & Environment (Uganda), University College London (UK), UNESCO and the IAEA, the Groundwater & Climate in Africa conference brought together more than 300 water scientists, managers and policymakers including parliamentarians from

23 countries in Africa and 14 countries from around the world. The conference featured 96 presentations that contributed to six strategic themes, including the impact of climate variability and changes on groundwater-based livelihoods and groundwater-fed ecosystems, monitoring and modelling of groundwater replenishment and use, estimation of groundwater resources and demand as well as groundwater management in arid, semi-arid and humid environments within a changing climate. Among a range of scientific issues, participants highlighted the strategic importance of groundwater storage, in light of the fact that global warming is predicted to result in fewer but more intense precipitation events and thereby increase uncertainty and variability in surface water resources and soil moisture. With over 20 hours of dedicated discussion time culminating in two round-table sessions, participants were able to translate scientific and policy-related research findings into concrete technical and policy recommendations, summarised in the 'Kampala Statement', for national governments in Africa, regional, basin-wide and transboundary organizations as well as for international fora, including the 5th World Water Forum and Copenhagen Climate Summit in 2009. The Kampala Statement as well as all conference abstracts and presentations are available online via http://www.gwclim.org.

Meetings

- The Isotope Hydrology Analytical Network (IHAN) is a group of isotope hydrology laboratories cooperating closely with the IAEA in water sample isotope analysis. It was informally established eight years ago to accommodate the ever-increasing number of samples being sent to the IAEA Isotope Hydrology Laboratory for analysis. Such sample analyses are mainly requested by IAEA Technical Cooperation project coordinators in Member States. These projects apply isotope hydrology methods in developing countries and are carried out by national counterparts selected by governments of these countries with assistance, backstopping and financial support of the IAEA. Within the IHAN network, 14 laboratories have provided sample analysis - some more than 500 and some up to several thousand - for the IAEA over the last decade. Several other laboratories are involved only in special measurements (like AMS-^{14}C, ^{87}Sr or ^{3}He/^{4}He analyses). An annual total of 5 000 to 10 000 measurements are conducted for IAEA Technical Cooperation projects by IHAN and the IAEA. In order to assure the quality of data produced by participating laboratories, an informal quality control scheme was initially established. A small percentage of all samples were analyzed in duplicate at the IAEA Isotope Hydrology Laboratory and the data compared, with corrective actions applied in case of discrepancies. The necessity of splitting samples and routing them through the IAEA created a bottleneck, which slowed down the process. Alternatives were discussed at a first consultants meeting near the end of 2006. A comprehensive meeting of most IHAN laboratories was held between 8–10 September 2008, at the IAEA in Vienna. Managers from 12 IHAN laboratories and representatives of two candidate laboratories were present. Administrative procedures for the IHAN operation were discussed and streamlined to ensure an improved turnaround time in the future for sample analysis. In addition, a new quality control scheme was agreed upon. Laboratories participating in tritium and water stable isotope analysis will be supplied with a stock of numbered bottles from the IAEA, which should subsequently be included in the analysis of future sample batches. Their results will be compared with values calibrated beforehand by the IAEA and with parallel analyses of the same water samples at the IAEA. This will ensure a maximum of quality control for analytical data produced in any participating laboratory. It will further enable the early detection of possible offsets or analytical problems and therefore increase confidence in all produced data.

- The second coordination meeting on regional project RER/8/012 'Isotope Methods for Management of Drinking Water Resources in Water Scarcity Areas' was held at the IAEA headquarters from 10–14 November 2008. National and regional scale water-related activities and technical themes of common concern to the Technical Cooperation European region were discussed during the meeting. Possible joint activities on trans-boundary water resources and future activities in the region were analysed.

- The National Symposium on Isotope Techniques in Hydrology was held by the State Hydraulic Works (DSI) of Turkey from 13–17 October 2008 in Istanbul. The IAEA was represented at this meeting by Mr. Pradeep Aggarwal and Mr. Türker Kurttas from the Water Resources Programme. Key lectures on the application of isotope techniques in various fields of hydrology were delivered by staff members. The aim of this symposium was to gather water-related professionals and isotope hydrology researchers together. More than 150 professionals and academics from different governmental organisations, universities and research institutes attended the symposium. Some of the

participants, academics and students were supported in part by the IAEA. At the end of the symposium, a round table session was held to provide an open forum for participants and decision makers to discuss Turkey's issues in the fields of isotope hydrology and water resources management.

- The Second Research Coordination Meeting (RCM) under Coordinated Research Projects (CRP) on 'Isotopic Techniques for Assessment of Hydrological Processes in Wetlands' was held at the IAEA in Vienna, Austria from 8–12 September 2008. The purpose of this CRP was to develop a framework and methodology under which isotopic techniques could be applied to assess hydrological processes in wetland ecosystems, which have been drawing the interest of the scientific community and which are also becoming an important management issue. The primary purposes of the second RCM were: (i) to present and review the progress of projects and activities conducted since the first RCM, (ii) discuss and set the final output of the CRP and the work plan geared toward that output, and (iii) further promote and coordinate cooperation among the projects. RCM participants from 17 countries gave presentations of their projects. Discussion meetings were held to seek common objectives among CRP investigations, to establish ways to remotely promote cooperation and coordination among the investigators of the CRP, and to determine a tentative structure for final outputs of the CRP within a 3-year timeframe. A tour of the Isotope Hydrology Laboratory also took place, which included an explanation of the recently acquired laser machine.

New Staff Members

- Mr. Philipp Klaus joined the Isotope Hydrology Laboratory in June 2008. He was previously employed for eight years at the IAEA Agrochemicals Laboratory in Seibersdorf as a chemical engineer. His main responsibilities include tritium analysis (especially electrolysis, counting and quality control of tritium measurements), $^{3}H/^{3}He$ sample preparation, related hardware maintenance, and the provision of support for the laboratory database and laboratory computer network.

- Mr. Luis Eduardo Toro-Espitia joined the Isotope Hydrology Section as a consultant on 7 April 2008. Mr. Toro-Espitia works with the compilation of isotope data for the Latin American Atlas, and he supports several TC projects on this continent. Formerly, he worked as a hydrogeologist at two local environmental agencies in Colombia. He also took part as an expert in TC projects for four countries in Latin America. His interests include the study of paleo-groundwaters and the use of stable isotopes as indicators of climate change.

Departing Staff Members

- Mr. Manzoor Ahmad Choudry joined the Isotope Hydrology Section in 2006. He was formerly at the Division of Isotope Applications at PINSTECH, Pakistan Atomic Energy Commission (PAEC), where he headed the Isotope Hydrology Group. During his stay at the IAEA, he assisted in isotope data compilation for the ISOSHIS (Isotope Hydrology Information System) database and in the preparation of the Atlas of Isotope Hydrology - Asia and the Pacific. He also contributed to the organization of the International Symposium on Advances in Isotope Hydrology and its role in sustainable Water Resources Management (IHS-2007) and in the preparation of the proceedings.

- Mr. Kshitij Kulkarni joined the isotope Hydrology Section in 2001 and left in September 2008. He has returned to his former institute in India, the Hydrology and Tracers Section of the Isotope Applications Division at the Bhabha Atomic Research Centre (BARC), Mumbai. His interests and work carried out during his stay at the IAEA included the assessment of aquifer systems affected by different natural and anthropogenic pollution sources such as salinization, arsenic or fluoride, as well as studies in the unsaturated zone and submarine groundwater discharge into the ocean. He was also engaged in the preparation of a number of the publications and outreach materials for the Water Resources Programme.

- Ms. Claudia Lust started in the Isotope Hydrology section on 29 May 2007 as M. Davin's replacement. She became SH secretary after C. Manica left in March 2008 and worked there until 30 September 2008 as section head secretary. It was her first post in the IAEA.

Training Courses

- The first group training in isotope hydrology held in French for African fellows was organized in Rabat, Morocco, for six weeks, from 10 November to 19 December 2008. The training was financed by

several technical cooperation (TC) national projects in isotope hydrology in African countries from which the participants came. It was held in Centre National de l'Énergie, des Sciences et des Techniques Nucléaires (CNESTEN) in Rabat and covered an overview of groundwater hydrology as well as the application of isotope and related hydrochemical techniques, including basic principles, field work and sampling techniques, laboratory work, and data analysis and interpretation. Main topics included: the use of isotopes for evaluation of aquifer capacity and recharge; the use of isotopes and solutes as indicators of groundwater pollution; step-by-step procedures for the analyses of stable water isotopes, tritium and carbon isotopes, and related laboratory management; and isotope and related hydrochemical data analysis and interpretation, among others. The training was organized to assist French-speaking fellows from African TC projects in the practical application of isotope techniques for water resource management in their respective countries in general, and more specifically to aid in capacity-building, and the development of knowledge and skills enabling activities in respective TC isotope hydrology projects, as well as the promotion of contact with fellows from other TC projects.

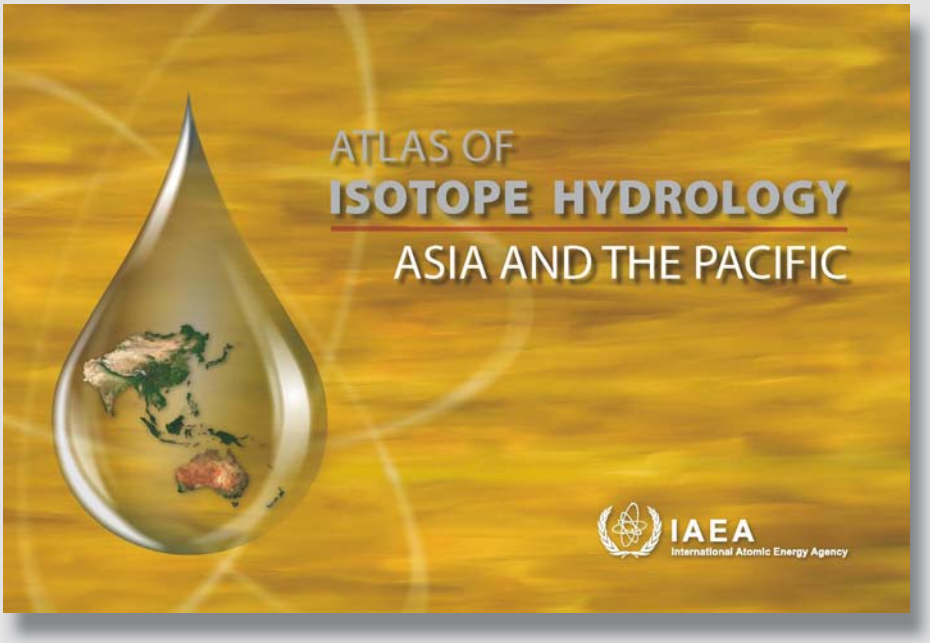
- The IAEA regional 'Advanced Training Course on the Application of Isotope Techniques', held 20–31 October 2008, was organized by the International Atomic Energy Agency (IAEA) in cooperation with the Government of Hungary through the VITUKI Environmental Protection and Water Management Research Institute and the Research Centre for Water Resources Development. The main purpose of the course was to provide participating young professionals with adequate theoretical and practical training in basic isotope hydrological applications, as well as groundwater flow and transport modelling. The course was addressed to professionals (hydrogeologists, hydrologists, and geologists) working in hydrological research and management of water resources. The participants were trained in how to integrate isotope hydrology techniques with groundwater flow and transport models to solve their water resources problems. Recharge area identification, groundwater flow dynamics, calibration of groundwater models through the use of isotopes, surface-to-groundwater interactions, and groundwater management for drinking water supplies were some of the topics included in the training programme. This course, like the previous one held in Montenegro in November 2007, was part of an effort supported by the IAEA via Technical Cooperation projects to address country-specific water resource management issues. Twenty-four trainees from Albania, Bulgaria, Croatia, Georgia, Hungary, Kyrgyzstan, The Former Yugoslav Republic of Macedonia, Lithuania, the Republic of Moldova, Montenegro, Romania, Serbia and Turkey, two external lecturers and Türker Kurttas from the IAEA's Water Resources Programme participated in the training session.

Training Videos

- A training video demonstrating analytical procedures used at the IAEA Isotope Hydrology Laboratory is near completion. It is dedicated to the training of fellows at the IAEA laboratory and to provide information to technical staff of other laboratories. The one-hour long video is separated into different chapters featuring major analytical procedures. For stable isotope analysis, it covers a variety of instruments and techniques (dual inlet IRMS, continuous flow IRMS, infrared laser spectroscopy; water/gas equilibration technique, Zn water reduction, high temperature elemental analysis, vapour infrared laser light absorption, and carbonate acid reaction). Tritium analysis, electrolytic enrichment and liquid scintillation analysis are described. The use of advanced methodologies like ^{3}He/noble gas analysis and CFC analysis are also covered. The chapters should allow for a deeper understanding of the steps needed for successful application of analytical techniques.

- The IAEA Water Resources Programme is finalizing a training video on the measurement of stable isotopes ($\delta^{18}O$ and $\delta^{2}H$) of liquid water samples using a laser absorption instrument. The video describes how to install and maintain the instrument as well as how to run samples. A companion procedure and data analysis spreadsheet are expected to be released with the video in 2009. ■

Atlas of Isotope Hydrology – Asia and the Pacific



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The Isotope Hydrology section is proud to announce the release of the Atlas for Isotope Hydrology – Asia and the Pacific, the second in a planned series following publication of the first Atlas of Isotope Hydrology for Africa in August of 2007. Nearly half of all freshwater used for drinking and irrigation worldwide is groundwater, on which irrigation and the world's food supply are dependent. Yet, the world's groundwater resources are not well understood. Water resources management and related policy development require widely acceptable scientific information on the hydrology of water bodies. Naturally occurring isotopes in water provide unique hydrological information and the associated techniques are highly cost effective. The applications of isotopes in hydrology have from the very beginning been part of the IAEA's programmes related to the peaceful applications of nuclear energy. The focus of the IAEA's work has been to develop appropriate methods for use in water resources management and to assist its Member States in using those methods.

The IAEA has helped create a large body of isotope data on the world's rivers, lakes and aquifers that can be used for resource assessment and management on local, regional and continental scales, and which can be further applied to understand and mitigate the effects of climate change. A number of isotope hydrology atlases are now being produced using these data. By making the data easily available to scientists worldwide, it is hoped that the IAEA can facilitate the integration of isotope hydrology into the practice of water resource management. This isotope hydrology atlas focuses on projects in IAEA Member States in the Asia and Pacific region, where environmental isotopes were used to assess water resources in terms of quantity and/or quality. It presents location maps of study areas, summary statistics and relevant data plots. Nearly 16 000 isotope records from 105 projects carried out between 1973 and 2007 in 16 Member States are included. For each country, a physiographic map is provided that shows major water bodies, locations of stations in the IAEA/WMO global network of isotopes in precipitation (GNIP) and the project study areas. For each project, a map of the study area is provided, together with data tables and plots for median and mean values of $\delta^{18}O$ and $\delta^{2}H$, average annual precipitation and air temperature, tritium and radiocarbon values.

The Isotope Hydrology Information System (ISOHIS), maintained by the IAEA, is the source of the hydrological and isotopic information used in the compilation of this atlas. Isotope data and relevant information from GNIP stations in Asia and the Pacific are available through the on-line application WISER at www.iaea.org/water. ■

For further information, please contact Luis Araguás at l.araguas@iaea.org or Türker Kurttas at t.kurttas@iaea.org

Isotope Survey Used to Better Understand the Danube

By Brent Newman[1], Wolfgang Papesch[2], Dieter Rank[3], Tomas Vitvar[1], Hana Hudcová[4], and Pradeep Aggarwal[1]

In the summer of 2007, a wide collection of samples were taken on the Danube River, starting in Regensburg, Germany and ending in the Black Sea, spanning a distance of over 2 375 kilometres. The results of this study are now available.

Figure 1: The Danube River in the Wachau, region. (Photo Credit: T.Vitvar/IAEA).

The Water Resources Programme and collaborating Austrian research partners have been supporting the International Commission for the Protection of the Danube River (ICPDR) to help improve understanding of the basin surface water and groundwater systems through the application of isotope techniques. In the summer of 2007, the ICPDR launched the second Joint Danube Survey (JDS-2) to collect information on the river's water quality and ecological status (Figure 1).

The survey entailed collection and analysis of samples for a wide variety of water quality parameters such as organics, nutrients, and metals, as well as analyses of sediments, fish and other biota. The survey began in Regensburg, Germany and finished 50 days later in the Black Sea. Samples were collected by ship at over 90 points along 2 375 km of the river covering 10 different countries (Figure 2). Results are now available on the ICPDR website www.icpdr.org/JDS. As part of JDS-2, the IAEA and collaborators established a sampling and analysis program for stable and radioactive isotopes. This was the first time isotope measurements have been included as part of a JDS. The main objectives of the isotope survey were primarily hydrological. Since there are only a few existing environmental isotope data from the Danube (especially from the lower Danube), the JDS-2 was a welcome opportunity to improve the data base for environmental isotopes in this region. Grab samples were collected within the upper one meter for stable isotopes of water (δ^2H and $\delta^{18}O$), and tritium (^3H) at the 95 official JDS sampling points, including 74 sites in the Danube and 21 sites in tributaries and arms. Additional points near the left and right banks, above and below the confluences of eight major tributaries, were sampled for stable isotopes and ^3H to provide information on mixing with tributary waters. A radon survey (^{222}Rn) was also completed using an on-board analyzer. This summary describes some example results from the isotope survey, and additional details and interpretations are planned for a future paper. Results for $\delta^{18}O$ from the official JDS-2 stations are shown in Figure 3. The $\delta^{18}O$ record exhibits three significant changes along the river. The first and largest change occurs after the confluence of upper Danube (higher $\delta^{18}O$ value from a mainly lowland drainage area) and the Inn (lower $\delta^{18}O$ value from a mainly alpine drainage area), reflecting the impact of the large Inn discharge. The second most-significant impact is in the area of the Tisa and Sava confluences, where the

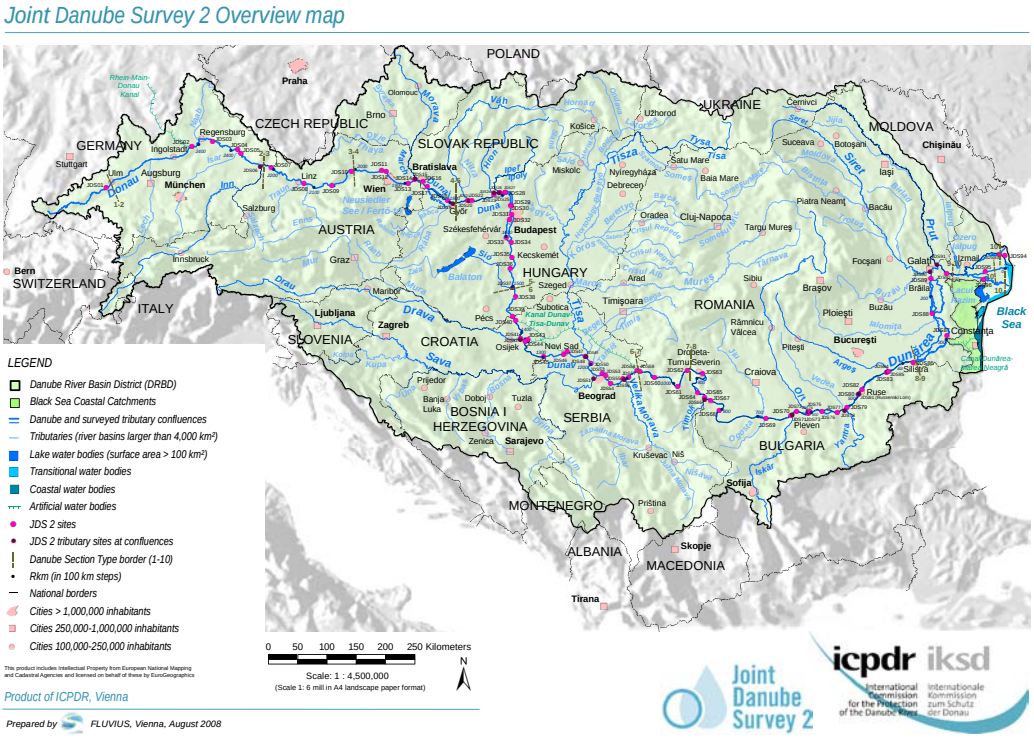

Figure 2: JDS-2 sampling points along the Danube River.

tributaries have higher $\delta^{18}O$ contents than the Danube. The third change occurs in the Iron Gate area and is related to the extreme precipitation event in Central Europe during 5–7 September (labeled 'high water influence' in Figure 1). According to the runoff data from the lower Danube, all the $\delta^{18}O$ values between Iron Gate and the river mouth increased by 0.2–0.3 ‰ as a consequence of this precipitation event. The total increase of 1.2 ‰ in $\delta^{18}O$ between the Inn confluence and the mouth of the Danube is mainly due to the decreasing influence of alpine runoff contributions and a corresponding increase of lower elevation contributions.

The natural production of tritium (^3H) by cosmic radiation in the upper atmosphere leads to a ^3H concentration of about 10 TU in actual precipitation in Central Europe. Local ^3H releases into the river system of the Danube Basin caused by human activities (nuclear power plants, nuclear industry) modify this 10 TU value. The evolution of ^3H along the Danube is shown in Figure 4 which mainly reflects tributary ^3H contributions and mixing within the Danube. The homogeneous and relatively low ^3H signal of the upper Danube area (e.g., around the Danube/Inn) is altered by temporally (pulse effects) and spatially variable (left-side or right-side tributary) contributions of high ^3H inputs from nuclear power plant discharges (note that "high" is only used in a relative sense, even the highest values detected in the study are well below any health limits). In case of JDS-2, these effects are pronounced for example in the Morava and Váh tributaries entering on the left side of the river. Preliminary qualitative data analysis shows that although the Váh contributes less than 10% of the total discharge of the Danube, the elevated ^3H signal it produces can be traced along the left side of the river below the confluence. The Váh ^3H signal on the right side of the river, however, shows minor to no influence on the Danube. From below the Sava confluence and further downstream, a relatively uniform ^3H distribution is maintained with slight changes between values on the right and left sides of the Danube according to the incoming direction of the tributaries (e.g., the Velika Morava from the right, and Olt from the left). The uniform signal below the Sava might be related to the impact of the large September rain event

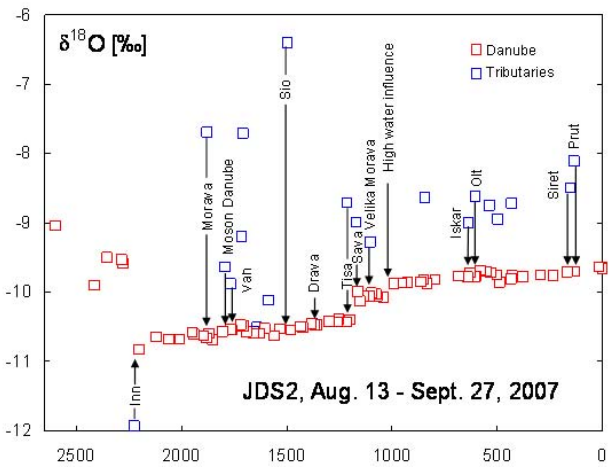

Figure 3: $\delta^{18}O$ along the Danube (Aug. 13 – Sept. 27, 2007).

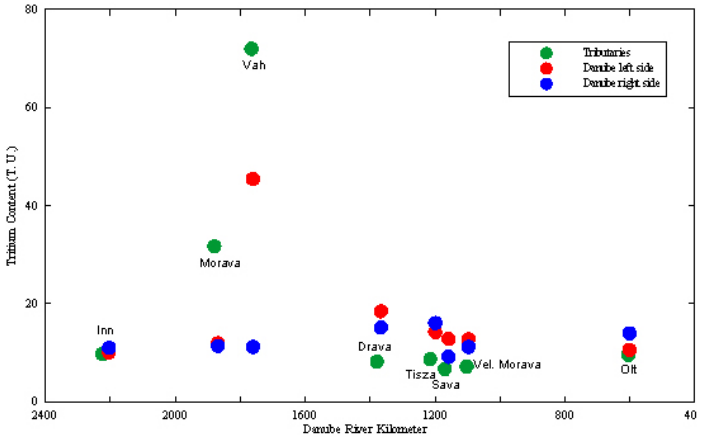

Figure 4: Tritium from JDS-2 sampling points (Aug. 13 – Sept. 27, 2007) in selected tributaries (green), and on the left (red) and right (blue) river sides of the Danube below the respective confluences. Note that the Morava, Váh, Tisza and Olt are left-side tributaries, whereas the Inn, Drava, Sava and Velika Morava are right-side tributaries.

mentioned earlier, as well as by potential infiltration and return groundwater flow through adjacent aquifers. Tritium values of the September precipitation in Austria that caused the elevated Danube discharges are around 10 TU, which is not significantly different from Danube water prior to the large rainfall event. There are additional ^{3}H sources to the Danube not discussed here. A limited number of sampling points did not permit delineation of the impacts of these other potential sources.

The ^{222}Rn data were collected using an on-board Durridge RAD-7 portable radon detector to identify potential locations with significant groundwater inputs. Although ^{222}Rn in natural waters can be affected by geology and other factors, elevated ^{222}Rn values have been shown to be an effective indicator of groundwater discharges in rivers and along coastal zones. It is an effective isotope indicator because groundwater values tend to be much higher than in rivers; surface waters lose radon relatively quickly to the atmosphere and ^{222}Rn production in rivers is much lower than in groundwater. The ^{222}Rn profile along the Danube has some interesting features and is shown in Figure 5. Overall, the values are low and the lowest values are effectively at the limit of detection as is typical for surface water. However, there are significant differences between some parts of the Danube and between the Danube and some tributaries. The overall trend is for higher radon concentrations in the upper Danube which suggests that this may be the area where groundwater contributions to the river are the largest (although tributary inputs may still be significant or even dominant). Some of the tributaries (e.g., the Sava, Velika Morava, and Siret) also have high ^{222}Rn, which suggests they have groundwater inputs in the vicinity of the JDS-2 sampling points.

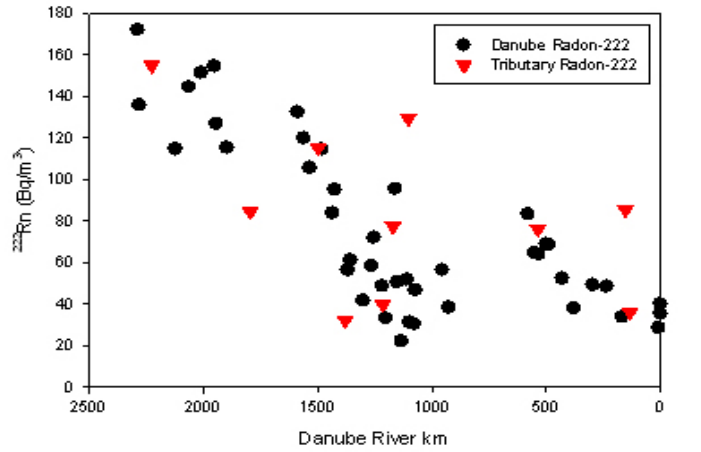

Figure 5. Radon-222 content in the Danube Basin (Aug. 13 – Sept. 27, 2007). Uncertainty is less than 30 Bq/m³.

Conclusions

A variety of isotope data (i.e., $\delta^{2}H$, $\delta^{18}O$, ^{3}H, and ^{222}Rn) were collected as part of JDS-2. The preliminary interpretations discussed here support the conclusion from previous isotope work in the Danube which emphasized the dominant role of tributaries and in-channel mixing over direct groundwater inflows from aquifers along the Danube. The isotope data reported here also provide an important environmental baseline for implementation of the EU Groundwater Framework, more specifically in monitoring and conceptual assessment of river/groundwater interactions in the major transboundary aquifers of the Danube basin. ■

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Uranium Isotopic Disequilibrium Used to Study Continental Intercalaire Aquifer

By K. Zouari and N. Chkir, Laboratory of Radio Analysis and Environment of National School of Engineering, Sfax, Tunisia

The Continental Intercalaire Aquifer in Southern Tunisia - one of the largest aquifers in the world - is considered to contain essentially fossil groundwater, and is threatened by local water extraction.

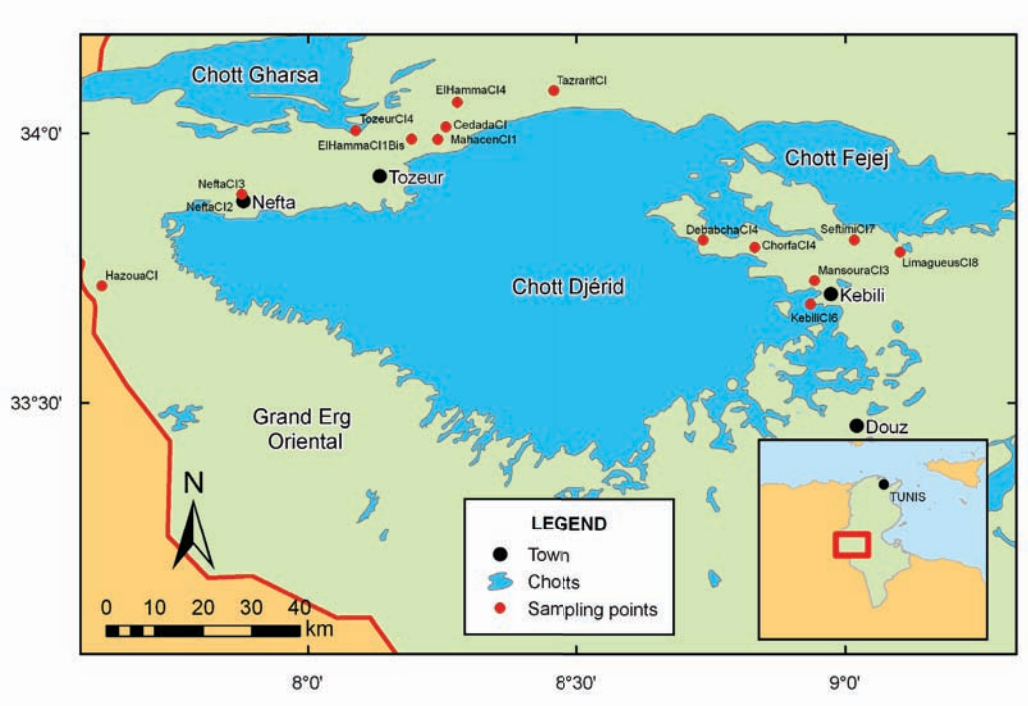

Figure 1: Sample boreholes for Continental Intercalaire aquifer Southern Tunisia.

Uranium as a Tracer of Groundwater

Normally, the fractionation of heavy nuclides in chemical processes is negligible, particularly in natural environments. However, the disequilibrium between ^{238}U and ^{234}U in rocks and their leached solutions, or in natural water, has been found to be the rule rather than the exception. The abundance of the two uranium isotopes, ^{234}U and ^{238}U, has been used extensively to characterize groundwater. Uranium contents in groundwater commonly depend on geochemical conditions such as pH, Eh, and the presence of other dissolved ions, while the mobility of uranium is affected adsorption or desorption processes of U ions and precipitation or dissolution of U-bearing minerals (Ivanovich and Harmon, 1992). Aquifers where groundwater and aquifer rock are in close contact are favorite systems for both chemical and physical differentiation, especially when rock-water ratio, surface area and residence time have large values. These conditions are often observed in deep, fossil groundwater.

Several studies (Osmond and Cowart, 1976; Dabbous and Osmond, 2001) have proven that the use of uranium series disequilibria in describing aquifer processes can help to resolve hydrogeological problems.

The main purpose of this method is to classify aquifers (as steady-state, augmenting or decaying systems). Aquifers are classified in terms of U-content: oxidized aquifer on 'normal' U-content strata (values between 1 and 10 ppb); oxidized aquifer on enhanced U-content strata (values higher than 10 ppb); reduced aquifer on low U-content strata (values lower than 1 ppb); and in terms of $^{234}U/^{238}U$ activity ratios: "normal" world-wide groundwater (values between 1 and 2), the possibility of formation processes (values higher than 2) or remobilization (values lower than 1). The common method used to identify sources and mixing

proportions of aquifer water is to diagram the $^{234}U/^{238}U$ activity ratio against the reciprocal of uranium content.

The Continental Intercalaire (CI) Aquifer

Data of dissolved U and isotopic activity ratio in groundwater samples from the Continental Intercalaire aquifer in Southern Tunisia are used to evaluate the applicability of the model in the area (Chkir and Zouari, 2007).

The Continental Intercalaire aquifer which underlies all the Lower Sahara, is one of biggest aquifers in the world extending over a surface of 600 000 km². This aquifer is mainly lodged in the Lower Cretaceous continental formations (Neocomian, Barremian, Aptian, and Albian) with high variations of facies and thickness. These formations are between 1 550 and 2 300 meters deep. The groundwater system consists of two great sectors, a western zone where the main flow path is directed eastward to the discharge zone, and a south western zone where the main flow path is to the northeast. This second sector, Erg Oriental Basin, extends from Algeria to Tunisia; its natural discharge is located at the Gulf of Gabès. This aquifer is considered to contain essentially fossil groundwater resources. The sampling zone is located on both the Djérid and Nefzaoua basins (Figure 1). This area is characterized by an arid climate. Annual precipitation is highly variable spatially, temporally and averages less than 100 mm. The mean annual temperature is in the order of 21°C, while the evaporation rate is more than 1 700 mm/year.

Twenty groundwater samples collected along the paleoshorelines of Chott Fejej and Chott Djerid have been submitted to standard analytical procedures for determinations of the U content and Activity Ratio (AR) using alpha spectrometry techniques in the Laboratory of Radio-Analysis and Environment of the National School of Engineering of Sfax (Tunisia). Dissolved uranium in groundwater from the CI aquifer ranges widely (Table 1). U content and AR values show great variability where samples in all classification categories are present.

Table 1: Uranium in Continental Intercalaire, groundwaters.

U-content (ppb)		$^{234}U/^{238}U$ Activity ratio	
Min.	**Max.**	**Min.**	**Max.**
0.006	0.568	3.188	15.376

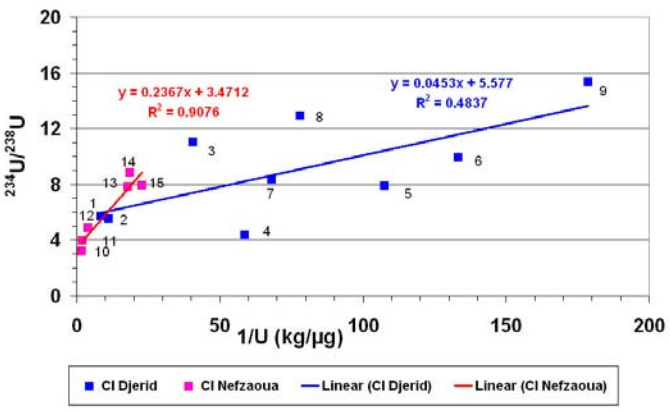

Figure 2: Reciprocal of U-content (kg/µg) vs $^{234}U/^{238}U$ activity ratio for CI aquifer.

Groundwater sampled from the CI aquifer has low uranium content (less than 0.5 ppb), while AR values are greater than 2 and range up to 15. The two regions of Djerid and Nefzaoua show great differences that can be related not only to lithostratigraphic formations but also to different origins of groundwater; for the Nefzaoua region it could be assumed that deep groundwater originated from the Dahar mountain recharge area and thus is of considerably younger age than the CI groundwater in the Djerid area. To interpret these data, $^{234}U/^{238}U$ activity ratios are plotted against reciprocal U concentrations on mixing diagrams; points typically exhibit a linear trend extending from lower left (low AR with high concentrations) to upper right (High AR with low concentrations). These can be interpreted as mixing lines; one end member is very dilute aquifer water which has experienced little leaching of uranium (upper right) and the other end member is the concentrated leachate of the host rock (lower left). Dispersion of points between these two end members exhibits water with various mixture ratios. The trend line is defined by two parameters: the y-intercept, which is the $^{234}U/^{238}U$ activity ratio of the uranium being leached from the host rock, and the slope of the trend line, which is the ^{234}U-excess per kg (U-equivalent ppb) and is characteristic of the pre-leach water.

The results of uranium isotopic analysis for the CI aquifer are plotted in Figure 2. Two groups of samples can be distinguished by two trends. Although variations in concentrations and activity ratios can be observed among groundwater sampled at the same region, these two mixing lines are consistent in regard to the complexity of the system. Groundwater samples from the Djerid zone are plotted close to a linear pattern from lower left to upper right. Along this straight line, uranium content increases, while $^{234}U/^{238}U$ AR decreases. It is a first leaching line: preferential ^{234}U dissolution is enhanced by a weak hydraulic gradient that

permits better water-rock interaction. The first end member (upper right), expected to be very dilute aquifer water that has experienced little leaching of uranium, corresponds for this area to water sampled from the oldest formation as observed by Dabbous and Osmond (2001) for the Nubian aquifer (Egypt). The second end member (lower left), expected to be concentrated leachate of the host rock, corresponds to groundwater in the northern part of the basin with the highest temperature (69°C and 63°C), which probably enhances uranium leaching from host rock. For the Djerid area, ^{234}U-excess is about 0.045 (U-equivalent ppb) and the AR of host rock uranium is 5.58.

Groundwater sampled from the Nefzaoua zone displays the same process between an end member characterized by a low uranium concentration with a high AR and a second-end member with high uranium concentration and low AR. Greater uranium concentrations (up to 0.6 ppb) are enhanced by the effect of high temperatures (around 65°C) and by greater hydraulic gradient, making water-rock exchanges more efficient than in the Djérid zone. For the Nefzaoua area, ^{234}U-excess is about 0.24 (U-equivalent ppb) and the AR of host rock uranium is of 3.47.

Conclusion

This study was performed to investigate the potential use of uranium isotopic variation for characterizing one of the greatest fossil groundwater resources in the world. The Continental Intercalaire aquifer has a wide range but low values of uranium (0.006 to 0.57 ppb) with relatively high ^{234}U/^{238}U activity ratios (3.2 to 15.4). High ^{234}U/^{238}U activity ratios have been reported for deep groundwater and have been explained either by a long history of high surface area interaction between a water of low uranium solubility and an aquifer rock with relatively higher concentrations of uranium (factor of 1 000) or by elevated temperatures that may enhance rock-water isotopic re-equilibration. Thus, high ^{234}U/^{238}U activity ratios are often observed in large aquifers with steady long-term flow systems such as the Continental Intercalaire aquifer and are characteristic of confined fossil groundwater.

The differences between the two Djerid and Nefzaoua areas as well as between the different sites in a given area can be attributed to local differences in the parameters governing the uranium isotope composition of the groundwater, such us uranium content of the rock material, properties of the aquifer rocks, or leaching rate for the two uranium isotopes. The most important result is the low uranium content and high activity ratio at CI sampling sites which indicates a confined fossil aquifer in reduced conditions. Determination of groundwater age remains challenging because data are only drawn from the discharge zone. Further investigations planned on the recharge area in the Algerian basin of the Continental Intercalaire would allow for assessment of recharge rates and mixing ratios.

Actually, exploitation of Continental Intercalaire groundwater is less than the aquifer's potential, but the steady state is threatened by local high water extraction. Refined knowledge should contribute to improved groundwater sustainability through a management strategy based on better comprehension of the intrinsic characteristics of the aquifer, groundwater flux, and groundwater sources.

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Editor's Note

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Isotopes and Hydrochemistry in Large Sedimentary Basins: Leon Valley Aquifer, Mexico

By Alejandra Cortes, UNAM, Autonomous University of Mexico, Mexico City, Mexico

The IAEA Water Resources Programme will help to map heavily used and precious resources in the Leon Valley to gain a better understanding of the dangers the aquifer faces, and its production capacity.

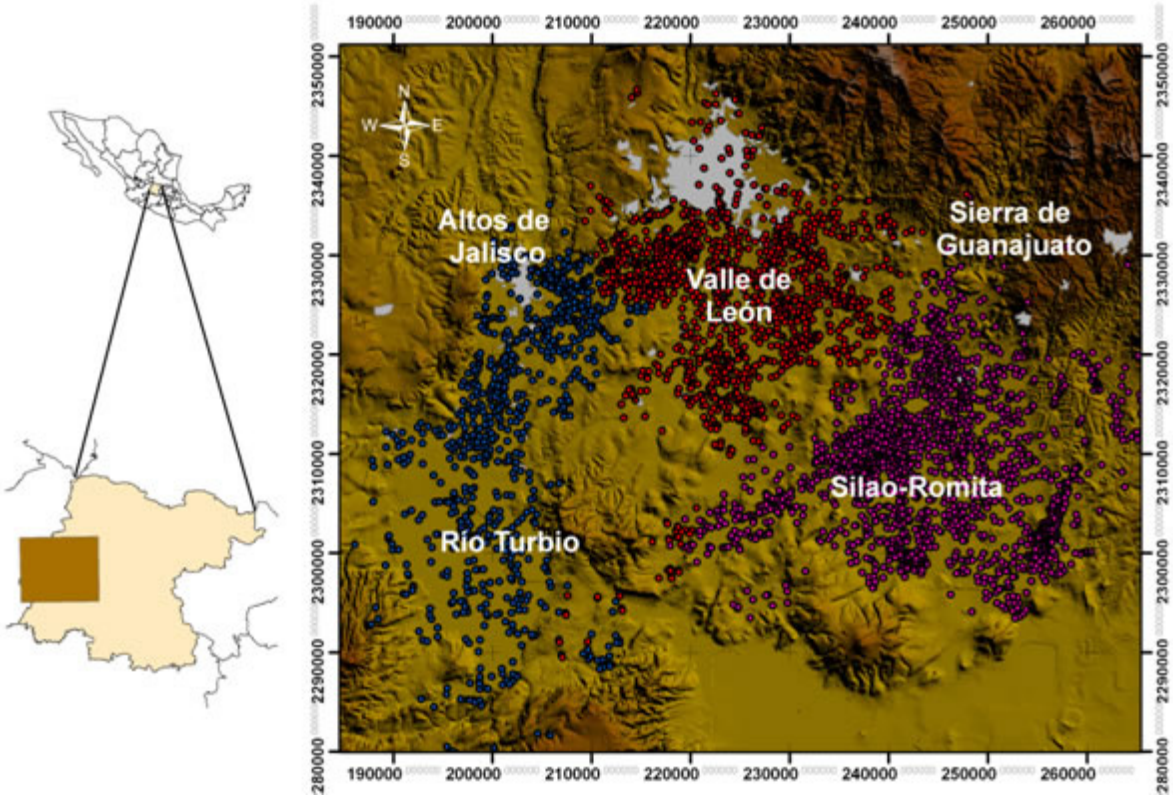

Figure 1. Location and geographical distribution of deep wells in the three sectors differentiated in the Valle de Leon aquifer, Mexico.

The Autonomous University of Mexico (UNAM) is conducting, in cooperation with a number of governmental institutes responsible for water resources management and with the assistance of the IAEA, a comprehensive hydrogeological study of the Leon Valley aquifer in Central Mexico. This important aquifer is located in the north-western part of Guanajuato State, Central Mexico. (Figure 1) The Leon valley is a thick sedimentary basin situated in the vicinity of the Transmexican Volcanic Belt, which crosses the country from the Atlantic Ocean to the Pacific Ocean.

Most of Guanajuato State is mountainous, and thus comprises recharge areas to several large sedimentary aquifers in Central Mexico. The Leon valley aquifer is located about 300 km north of Mexico City, and extends over ~3000 km^2 in a relatively flat area, locally called Bajío Guanajuatense, with a mean elevation of 1 750 masl. It is a tectonic depression filled with sedimentary materials eroded and transported from nearby mountainous areas (Figure 2). Several important urban centres and industrial centres have developed above the aquifer. The availability of good quality water allowed for the development of one of the most productive agricultural areas of Mexico, as well as of important industrial factories. Groundwater is being intensively used since the 1950s through the drilling of deep boreholes (up to 300–400 m). It is estimated that more than 6 000 wells now extract groundwater in the Leon valley, representing about 25% of all deep boreholes drilled in Mexico.

The relevance of groundwater in this region and problems related to its use go back in time several decades. The impact of the releases of heavy metals, mostly Cr (VI) salts, incorporated into wastewater from tanneries and into surface and groundwaters, is well-documented and has been studied for several decades. Guanajato State is also a well-known case study (Figure 3) in the hydrological community

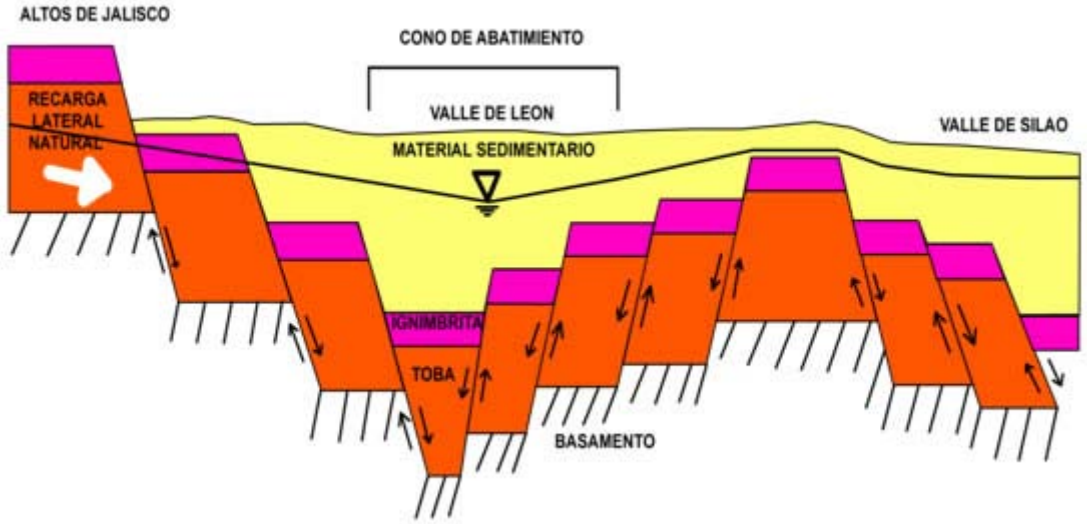

Figure 2. Simplified geological cross-section of the Valle de Leon aquifer, showing the main units conforming the main aquifer.

due to involvement of local stakeholders in groundwater management. This state is well-known for pioneering the implementation of educational programmes on water resources, as well as for the establishment of dedicated water agencies to compile hydrological information and design water management strategies. The general perception is that the aquifer is vulnerable to several pollution sources but only a partial assessment of the aquifer's water resources has been conducted.

Despite great concern on behalf of the general public and water authorities, a comprehensive assessment of the basic characteristics of the aquifer has never been completed.

Figure 3. Discharge of untreated sewage and industrial wastewater are a major concern for groundwater protection. (Photo Credit: L.Araguas/IAEA).

Only local studies have been carried out, which focussed on specific aspects, such as piezometric levels, water quality, fluoride contents, chromium contamination, etc. Several conceptual models delineating the main recharge areas, flow paths and discharge mechanism were proposed several decades ago, but they have not been validated. Also, there is limited knowledge of the dynamics of the deep groundwater. Several mixing scenarios involving three main water types have been proposed to explain available isotope and hydrochemical information.

Current hydrogeological studies, supported by the IAEA through Technical Cooperation project MEX/8/025, are being implemented in two phases. The Mexican counterpart at UNAM has compiled historical hydrogeochemical data and has conducted several field campaigns to collect water samples for hydrochemical and isotope analyses. Hydrochemical data and stable isotope data have been interpreted and reported in a number of thesis and scientific publications. During the first phase of the project, the isotopic composition of precipitation was monitored at a number of stations, using locally designed rain gauges. Groundwater dating of different water types identified in the first phase of the project will be carried out in the second phase of the project. ■

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Involving GLOBE Schools in a Study of the Stable Isotope Composition of Precipitation in Croatia

By: Z. Roller-Lutz [1], M. Mandić [1], H. O. Lutz [1,2]

Students in Croatia contribute to gathering and analysing precipitation information, used to support the IAEA's ongoing GNIP programme.

Karst is characterized by high permeability, porosity and crevices in which water moves in complex subterranean networks. Therefore, water resources in karst areas are very sensitive to pollution. This is of particular significance for Croatia, since about 50% of the country is karst, and the country's water management is a national priority. It is thus of vital interest to have as complete as possible knowledge of all factors which have input into the water system, including precipitation. Besides meteorological data, isotopic tracers are important tools to understand and quantify this complex problem. The isotopic composition of water is determined primarily by the passage of water into and through the atmosphere; the imprint on water bodies through precipitation forms the basis of many hydrological studies. It is usually expressed by abundance ratios R for $^{2}H/^{1}H$ and $^{18}O/^{16}O$, respectively, in terms of the so-called δ-value, $\delta(‰) = R_{sample}/R_{standard} - 1$, with $R_{standard}$ as the abundance ratio of an internationally accepted standard (e.g., the Vienna Standard Mean Ocean Water, VSMOW). Only sparse and scattered information exists, however, about the isotopic composition of precipitation in Croatia.

The GLOBE program appears particularly suited to remedy this problem. GLOBE (Global Learning and Observations to Benefit the Environment) is a worldwide primary and secondary school-based science and education program. In Croatia, about 100 schools are involved in GLOBE, and at present 24 contribute to a nationwide collection of precipitation (Figure 1). This activity is supported by the IAEA Research Project.

Students interested in the GLOBE program collect and determine amounts of daily precipitation, measure air temperature and send monthly averaged water samples to the Stable Isotope Laboratory (SILab) at Rijeka University. At the SILab, samples are analysed for their conductivity, pH, dissolved oxygen, salinity and isotopic composition in regards to $\delta^{2}H$ and $\delta^{18}O$. The δ-values are determined in a Thermo-Finnigan DeltaplusXP mass spectrometer using a combination of dual inlet and equilibration unit as periphery. The samples are equilibrated with H_2 and CO_2, whereby their isotopic composition is transferred to these

Figure 1: The participating GLOBE schools in Croatia.

gases and then analysed in the mass spectrometer. The required working standards were produced by collecting waters of different δ-values and storing them under nitrogen gas in stainless steel barrels. Their δ-values were calibrated through comparison with IAEA standards. Since the first results of this project already demonstrate the complexity of the meteorological situation in the country, it is appropriate to briefly look at the location of the country and corresponding implications.

Climate and Geomorphology of Croatia

Croatia is located in Southeast Europe, bordering on the Adriatic Sea. The climate is moderate. Generally, the islands and the coast have a Mediterranean climate, while in most inland areas it exhibits a more continental character. From autumn until spring, Iceland cyclones can cause weather instability over the northern Adriatic, frequently accompanied by secondary Mediterranean cyclogenesis with strong southerly winds along the coast and heavy precipitation, called 'jugo'. In summer, Azorean and Siberian anticyclones result in quite stable conditions, often with strong, dry northerly winds - 'bura' at the seaside. Regional and local orographic diversity have an important

influence. Highlands and mountain chains between the flat Pannonian plain in the north and the sea in the south provide a rather efficient divide and mitigate weather exchanges between north and south. Average temperatures show quite pronounced regional variations: in winter they range from -2ºC inland with snow in the mountains to 5ºC along the coast, and in summer they range from 15ºC to 25ºC, respectively.

The First Results of this Cooperative Project

The $\delta^{18}O$ values for three typical stations are shown in Figure 2: Karlovac (inland), Murter (seaside) and Gerovo (Gorski Kotar). The Karlovac and Murter data are characteristically different, as expected for inland and seaside stations. In parts, the Gerovo $\delta^{18}O$ values nicely follow the inland data, but in winter months (despite low temperatures) they exhibit a more maritime influence (i.e., higher $\delta^{18}O$ values). Such complex behaviour is also found for many other (even closely neighbouring) stations. This indicates that weather conditions can be quite variable on scales of time as well as distance.

Electrical conductivity usually lies well below 100 µS/cm. In a few cases (without clear correlation to other data) it lies between 100 and 200 µS/cm. Such variations are presumably caused by local effects, since no correlation exists even between neighbouring stations.

Most samples are slightly acidic (pH < 7). In March and September 2007, pH values are very slightly elevated at a few stations, inland as well as seaside, while in October and November the rain is rather acidic at three inland stations. These excursions seem to be local effects, too.

The d-excess, $d = \delta^2H - 8 \cdot \delta^{18}O$ [Dansgaard 1964], is a measure of kinetic fractionation effects and is a useful quantity to indicate the origin of precipitating air masses. The tendency is a higher d-excess in winter compared to summer months, and the seaside station Murter has a considerably lower d-excess compared to the more continental stations Gerovo and Karlovac. The general belief is that d-values of around 10 stem from Atlantic air masses while higher d-values possibly indicate the influence of air from the southern Mediterranean (North Africa). The real situation appears to be fairly complex. Using HYSPLIT back-trajectory calculations [Draxler and Rolph 2003, Rolph 2003], we have as an example analysed the month of November 2007 for Murter and Karlovac in more detail. At both stations the main precipitation events are caused by air masses moving in from various origins, namely, North

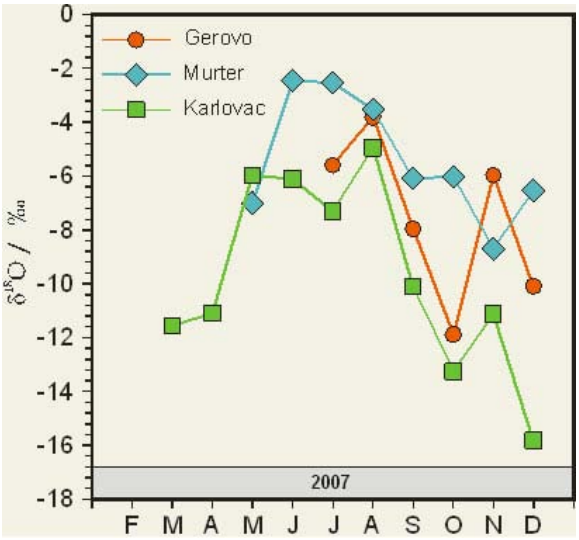

Figure 2: $\delta^{18}O$ values at the three stations.

Africa and the North Atlantic, as well as (particularly in the case of Murter) masses which circle for a considerable time over the Central Mediterranean in secondary cyclones. The country's topography plays an important role, too, and the question of what determines high or low d-excess certainly deserves more study. Although these studies began less than one year ago, they have already produced some interesting data. For example, they have demonstrated the very complex weather conditions in Croatia. Occasional sampling irregularities are mainly caused by standard open precipitation collectors due to evaporation fractionation, especially in dry periods (e.g., during school vacations in summer). In the future, specially designed collectors for monthly precipitation collection may be more appropriate to aid the sampling effort and prevent evaporative losses. ■

For further information please contact Türker Kurttas at t.kurttas@iaea.org

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2) Physics Faculty, Bielefeld University, Bielefeld, Germany

The Spatial Domain of Isotope Hydrology — Maps and more

The Isotope Hydrology section is using a sophisticated system of counting and mapping to recover information about different regions of the earth and present it in a digestible manner to create a solid knowledge base for those employing isotope techniques.

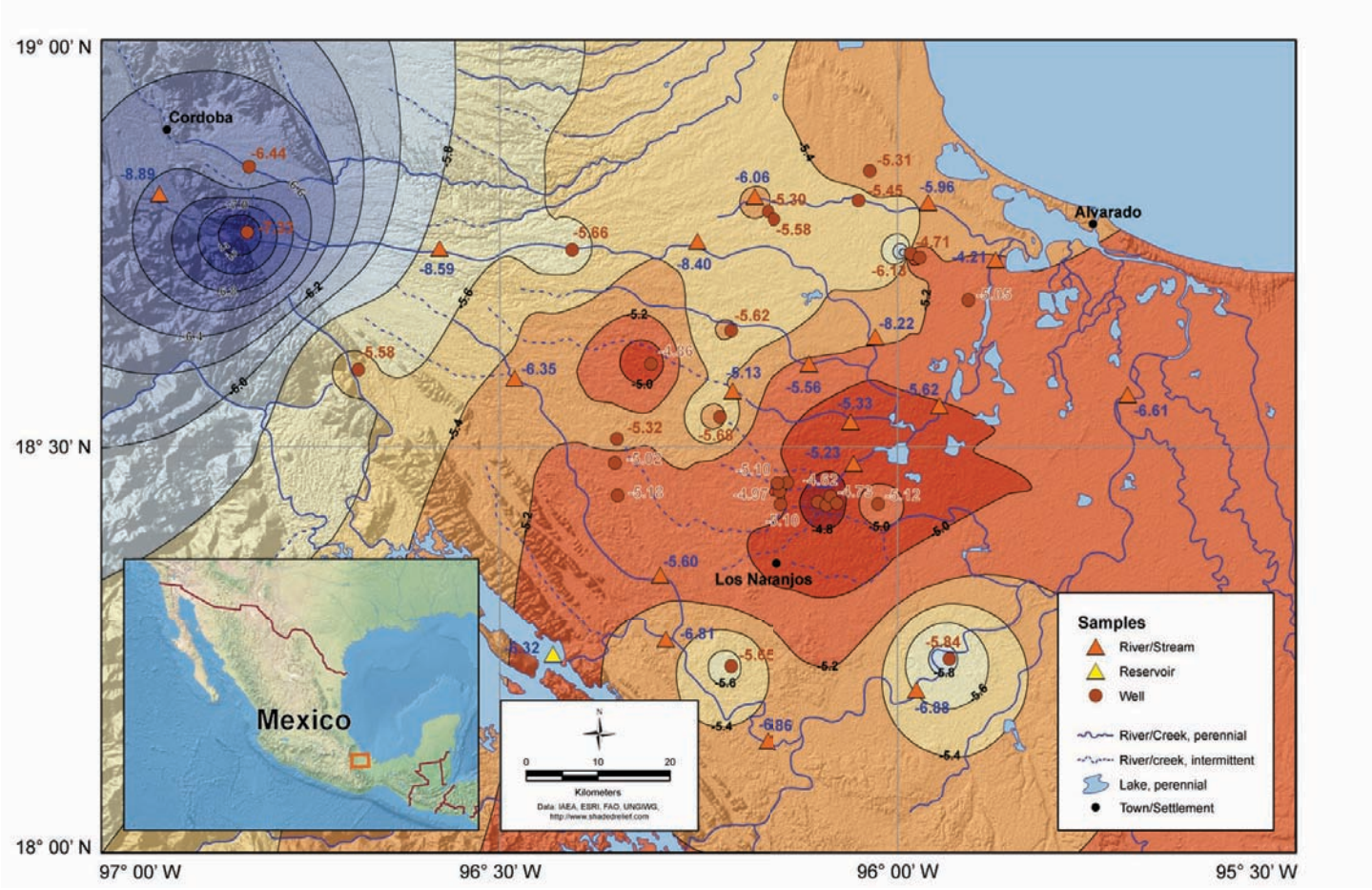

Figure 1: Map created at the IAEA using several sources.

From a cartographic perspective, recent decades have brought overwhelming technological change. We have not only seen the focus shifting from paper maps to digital data, but also the rise of multiple pathways for their dissemination via the World Wide Web. Following this trend, the Isotope Hydrology Section has not only strengthened its efforts to gather and disseminate isotope data from past and present Technical Cooperation and Coordinated research projects, but has also launched an on-line application for their distribution.

The publication of the Isotope Hydrology Atlases of Africa, and Asia and the Pacific Area demarcate another milestone in the turning of attention towards development of suitable techniques for data management and publication. Transferring this knowledge to counterpart institutions and encouraging them not only to establish their own national databases but also to conduct synthetic research will be one of the Isotope Hysdrology section's rationales for the future.

There are many important elements to the process used by the IAEA to gather and present data:

Data Acquisition

Digitizing and geo-referencing (i.e. assigning a spatial attribute such as latitude/longitude coordinates) data is a long and sometimes costly process, but it represents

Success story: Rio Blanco Basin, Los Naranjos, Mexico

Since finalization of the Isotope Hydrology Atlas of Asia and the Pacific area, the Isotope Hydrology Section has shifted its focus on creating a suitable database for a future Isotope Hydrology Atlas of Latin America. After setting up a task list for this undertaking, the IAEA archives were consulted in search of suitable material. This process revealed quite a lot of analogous material which was meant to be transformed into digital datasets. In the case of the Los Naranjos study, the map was scanned and geo-referenced using reference points obtained from Google Earth. Consequently, the sampling points could be digitized and the spatial domain could be attributed to the hydrological data. Finally, a modelling exercise using an Inverse Distance Weighted (IDW) algorithm supplied by ArcGIS 9.2 was conducted. Moreover, important background information was gathered to fill out the picture.

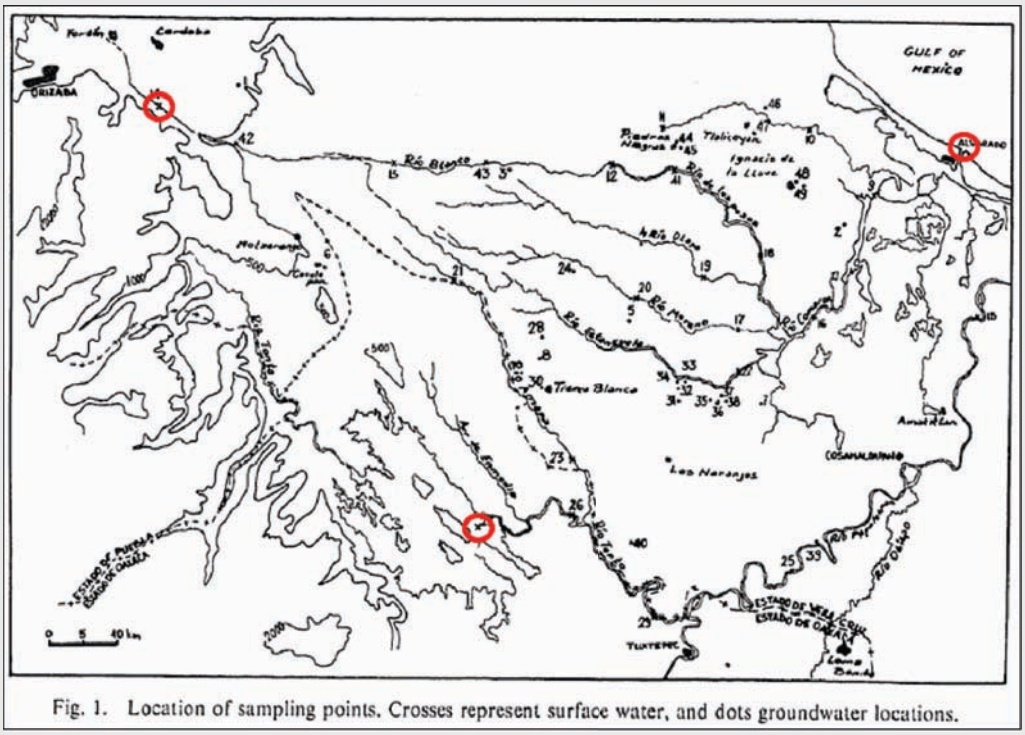

Figure 2: Old analogous map from which data is taken.

a significant value-enhancement of hydrological data. Adding spatial attributes allows for the extention of data visualization from a simple plot into the second - if depth information is provided - or even third dimension. Currently, a number of tools are available for free on the World Wide Web to support this process. Google Earth software http://earth.google.com, in particular, provides the user with global coverage of various spatial data which may help in assigning coordinates etc.

Mapping Tools

Certainly a key tool in this process is the Geographical Information System (GIS) which has allowed broad access to a number of scientific disciplines, since few of these deal with data that does not include a spatial domain. A GIS includes utilities for data storage, editing (such as digitizing coordinates) and visualization. Moreover, extensions provide the user with various capabilities for the geo-statistical treatment of data.

Modelling

Geospatial modelling may provide important input for decision-making processes in water resources management. Various products are available which employ a great number of algorithms. The suitability of a certain algorithm for a distinctive purpose has to generally be considered on a case-by-case basis. ■

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References:

PAYNE, B.R. and SAINZ ORTIZ, I. (1979): Determination of the Mechanism of Recharge in the Los Naranjos Area in Mexico Using Environmental Isotope Techniques, Water Resources. Res., 15(1), 171-175.

Following the Paths of Rivers

The recently launched Global Network of Isotopes in Rivers (GNIR) is used to accumulate data on isotopes in rivers and thus discover the impacts of climate change and human use, as well as river/stream/aquifer interactions.

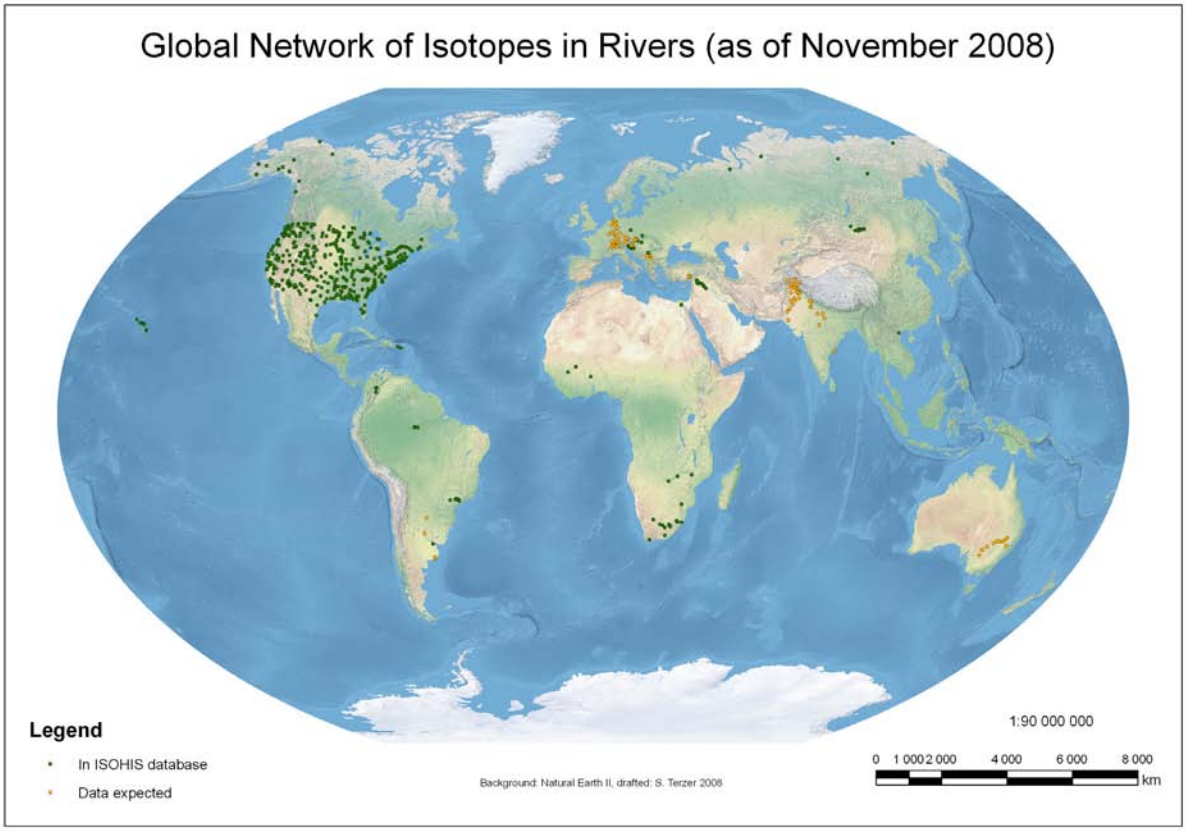

Figure. 1: Map of current sampling points.

The GNIR, launched in 2007, is a system developed by the Isotope Hydrology section to compile isotope data on river water, thus complementing the 45-year-old IAEA/WMO Global Network of Isotopes in Precipitation (GNIP). GNIR aims to use isotope data to gain an improved understanding of stream/aquifer interactions, the impact of climate changes on river runoff, and most especially human impact on river discharge. Recent studies suggest that the impact of storage areas, diversions and the redirection of streamflow for water supply, hydropower, and irrigation might surpass the impact of recent and anticipated future climate changes on river runoff. The consequences of these shifting variables include changes in frequency and extent of flooding, increased sediment load, altered groundwater recharge, and degradation of water quality and riparian ecosystems, often resulting in political disputes or upstream-downstream inequities.

Currently (Figure 1 – map of current sampling points) the GNIR consists of data from approximately 500 sampling points worldwide. Three types of data are distinguished: first, regularly monitored river stations with testing occurring a minimum of once a month and with a sampling period of at least two years, second, instantaneous spatial or profile-longitudinal surveys, and last, all remaining ad-hoc data from IAEA Technical Cooperation Projects, IAEA Coordinated Research Projects and other scientific studies worldwide.

Several stations established around 2000 are a good example of regular GNIR-monitoring. They have been maintained during and beyond the CRP 'Design criteria for a network to monitor isotope compositions of runoff in large rivers' (2002–2006), and include La Plata, the Indus, the Zambezi, the Murray-Darling, or the Sava (Slovenia). Other examples of successful monitoring include stable isotope sampling of American rivers performed in the 1990's, or isotope datasets from rivers in Germany, Austria and Switzerland, maintained for decades. Data from the transboundary Pan-Arctic river database (http://www.r-arcticnet.sr.unh.edu) have been added recently, extending isotopic fingerprinting of streamflow to rivers such as the Lena, the Yenisey, the

Kolyma, the Yukon and the MacKenzie. Examples of instantaneous longitudinal surveys include two from along the Danube river course, performed in 1988 and 2007 (see article Newman et al in this newsletter). The protocol for collection of river isotope data and their distribution into three data groups allows participants the freedom to act according to their conditions, resources, and research needs. The default grab sampling interval is monthly for regular monitoring, and where possible, samples should be collected at gauge stations. Analytical responsibility remains with the countries, but the IAEA may provide analytical support and/or technical assistance on an individual basis.

Current GNIR activities consist of further compilation of available river isotope data from past IAEA projects, and above all of the identification and search for existing river isotope data from national organisations and universities. All data are being compiled and checked, then made available through the online application WISER, accessible on the IAEA web page www.iaea.org/water (see contribution by Terzer in this newsletter). ■

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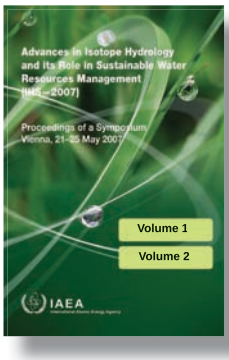
Meetings in 2008

- 2nd Research Coordination Meeting on Isotopic Techniques for Assessment of Hydrological Processes in Wetlands, Vienna, Austria, 14–18 April 2008.
- Consultants Meetings on Water Isotope Measurement by Laser Spectroscopy, Vienna, Austria, 19–23 May and 6–10 October 2008.
- Training Meeting Workshop on Isotopic Age Determination Techniques for Improved Understanding of Groundwater Resources, Argonne, USA, 16–27 June 2008.
- Coordination and Operational Requirements for Isotope Hydrology Laboratory Networks, Vienna, Austria, 8–10 September 2008.
- 2nd Research Coordination Meeting on Geostatistical Analysis of Spatial Isotope Variability to Map the Sources of Water for Hydrology Studies, Vienna, Austria, 6–9 October 2008.
- Workshop on Designing a Partnership Proposal for National/Regional Water Resources Assessment, 13–14 November 2008.
- Technical Meeting on Interpolation Methods of Spatial Isotope Data from Global Monitoring Datasets, Vienna, Austria, 17–19 November 2008.
- Consultants Meeting on Isotope Methods for Dating Old Groundwater, Vienna, Austria, 1–3 December 2008.

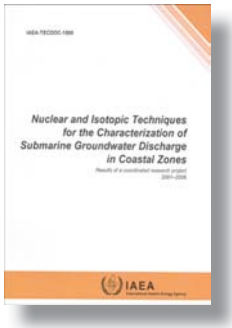
Meetings in 2009

- Consultants Meeting to Review and Synthesis of Isotope Data from Various Aquifers, Vienna, Austria, 19–21 January 2009.
- 2nd Research Coordination Meeting on Optimization of Irrigation Water Use Efficiency by Using Isotope Techniques to Evaluate Water Flux Below the Root Zone in Flood and Drip Irrigation, Vienna, Austria, 4–8 May 2009.
- Research Coordination Meeting to Develop Isotope Methods for the Assessment of Groundwater Sustainability by Age Dating of Base Flow, Vienna, Austria, 11–15 May 2009.
- Consultants Meeting to Produce a Guidebook on the Use of Isotopes for Monitoring Artificial Recharge and Aquifer Storage Schemes, Vienna, Austria, 15–19 June 2009.
- Regional Workshop to Review the Use of Isotopes in Groundwater Management (with ICTP), Vienna, Austria, 20–24 July 2009.
- Scientific Steering Committee Meeting for GNIP and Other Networks (in collaboration with WMO), Vienna, Austria, 16–20 November 2009.
- Consultants Meeting to Develop a Final Report on the Use of Oxygen Isotopes for Characterizing Aeration Levels, Vienna, Austria, 2009.

Publications



Historically, the IAEA has played a key role in advancing isotope techniques and in promoting the use of isotopes to address water resources sustainability issues worldwide. The quadrennial IAEA symposia continue to be an important component of the IAEA's mission in water resources management. The 12th symposium in the series was convened from 21 to 25 May 2007 in Vienna, and 'Advances in Isotope Hydrology and its role in Sustainable Water Resources Management (IHS-2007)' is based on the proceedings of this symposium. The objectives of the symposium were to review the state of the art in isotope hydrology, outline recent developments in the application of isotope techniques to water resources management, and the identification of future trends and developments for research and applications. Over 200 participants from 59 Member States participated in a series of invited lectures, poster sessions, round table discussions, and a scientific visit to the Danube River. The breadth of topics addressed was extensive and included analytical developments, the use of isotopes to understand land-atmosphere-biosphere interactions, river and surface water, development of deep groundwater resources, ecohydrology, urbanization and water resources management, carbon sequestration, waste management, artificial recharge, contamination problems, coastal zone hydrology, geothermal systems, agriculture and water research management and research frontiers.



The Isotope Hydrology section released in November the latest in a series of technical documents, entitled 'Nuclear and Isotopic Techniques for the Characterization of Submarine Groundwater Discharge in Coastal Zones'. Submarine groundwater discharge (SGD) is now recognized as an important pathway between land and sea. As such, this flow may contribute to the biogeochemical and other marine budgets of near-shore waters. These discharges typically display significant spatial and temporal variability, making direct assessments difficult. An initiative on SGD characterization was developed by the IAEA and UNESCO in 2000 as a 5-year plan to assess methodologies and importance of SGD for coastal zone management. The IAEA component included a Coordinated Research Project (CRP) on Nuclear and Isotopic Techniques for the Characterization of Submarine Groundwater Discharge (SGD) in Coastal Zones, carried out jointly by the IAEA's Isotope Hydrology Section in Vienna and the Marine Environment Laboratory in Monaco, together with 9 laboratories from 8 countries. In addition to the IAEA, the Intergovernmental Oceanographic Commission (IOC) and the International Hydrological Programme (IHP) provided support. This overall effort originally grew from a project sponsored by the Scientific Committee on Ocean Research (SCOR), which established a Working Group on SGD. This report examines several methodologies of SGD assessment, which were carried out during a series of five intercomparison experiments in different hydrogeological environments (coastal plains, karst, glacial till, fractured crystalline rocks and volcanic terrains). It reviews the scientific and management significance of SGD, measurement approaches, and the results of the intercomparison experiments.

This volume is the newly released French version of the IAEA-UNESCO publication 'Environmental Isotopes in the Hydrological cycle'. It provides an extended and detailed theoretical background on the use of environmental isotopes in hydrology, hydrogeology and related earth sciences. The publication also presents numerous case studies from all continents illustrating the application of environmental isotopes in studies dealing with water resources assessment and management. The material is designed as teaching material to be distributed to graduate students and participants in training courses and workshops on isotope hydrology. The publication consists of six sections, covering the following aspects: a) theoretical background on isotope geochemistry and general aspects of isotopes in the water cycle, b) isotopes of the water molecule in atmospheric waters, c) isotopes in surface waters, d) isotope tools in groundwater hydrology, e) use of isotopes and hydrochemistry in assessing vulnerability of aquifers to pollution, and f) use of isotopes to validate numerical models on groundwater flow and transport. This publication can support French-speaking graduate students and counterparts of Technical Cooperation and Coordinated Research Projects.

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