

Newsletter of the Isotope Hydrology Section
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In this Issue

From the Section Head	1
Users' views on GNIP and WISER	2
Progress Being Made in Dating Very Old Groundwater Using Noble Gas Isotopes	4
IWAVE Helping Improve National Water Resources Management	6
Examining Riparian Drinking Water Resources in the Danube Basin	9
News in Brief	11
Joel Gat: a pioneer isotope hydrologist 1926-2012	12
Characterizing the Manga Aquifer to Ensure Safe Drinking Water in South-east Niger	13
Sixteen Countries Join in Training Workshop	15
LIMS launched	16
Meetings in 2013	16



Sampling for groundwater age in Thailand (photo: courtesy of the Department of Groundwater Resources, Thailand).

From the Section Head

This edition of water and environment news focuses on aspects of isotope data collection and dissemination related to precipitation and groundwater resources. The IAEA's global network of isotopes in precipitation (GNIP) continues to be an invaluable resource for the traditional application areas of hydrology and climatology, and increasingly for a growing range of disciplines in ecology and forensics, creating new challenges for network operation and data management. We strive to facilitate as wide a use of GNIP data as possible and to expand the network, as feasible. To this end, user needs were gauged with a survey, and new methods of spatial analysis were applied to identify gaps in the network. Together with the new version of WISER — the IAEA's web application for GNIP data dissemination — we hope to be able to assure accessibility and long term sustainability of the network (see p. 2). Adequate characterization of groundwater flow remains a challenge in for most aquifer systems, particularly for large and deep aquifers with limited hydrogeological information. We are making significant efforts to expand the use of isotope age dating methods. Aquifers under study include two sectors of the Guarani aquifer in Brazil and Argentina, the Mekong delta aquifers in Vietnam and the aquifers under the Bangkok metropolitan area in Thailand (see p. 4). We have also made substantial progress in the IAEA Water Availability Enhancement Project (IWAVE) which aims to integrate the use of isotope hydrology for resource assessments, and in particular, aquifer mapping (p. 6). Finally, I am saddened to note the passing of Prof. Joel Gat from Israel. He was one of the original group of scientists who developed the field of isotope hydrology and made numerous contributions to it. I came to personally know Joel after coming to the IAEA in 1997 and it was a great privilege to have had his friendship.

..... P. Aggarwal

Users' views on GNIP and WISER



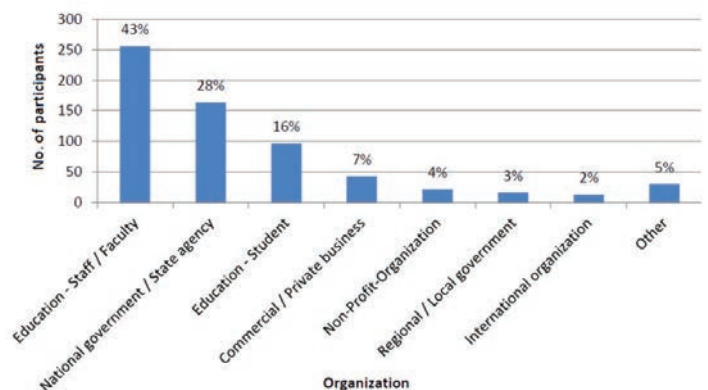
GNIP station in Austria (IAEA photo).

For more than 50 years, the Global Network of Isotopes in Precipitation (GNIP) has been an invaluable data source to define the local isotope baseline for researchers in a wide range of environmental disciplines. While the initial years focused on monitoring tritium levels, stable isotope applications have gained in importance over the last decades, with data users no longer limited to hydrology, but also coming from climatology, atmospheric sciences, and — in the last decade — ecology and forensics.

These new applications of water isotopes have in turn led to a drastic increase in the demand for raw and processed isotope data in precipitation, posing new challenges for maintaining and setting up new GNIP stations. Additionally, new methods of spatial analysis are being applied to improve global and regional isotope maps and to identify gaps in the network, while the workflows for sampling, shipment and analysis have been revised. Better spatial and temporal coverage of GNIP stations resulted in more precise global and regional water isotope maps. This new

interpolation method used by the IAEA, based on the use of regionally defined climatic regression coefficients, resulted in the production of more accurate isotope maps than those previously available. In addition, the new method provides the ability to generate isotope maps at variable time and space intervals (for example, monthly, growth season, or yearly at regional or local scales). Different isotope maps are accessible online to users of environmental isotopes in many disciplines (www.iaea.org/water).

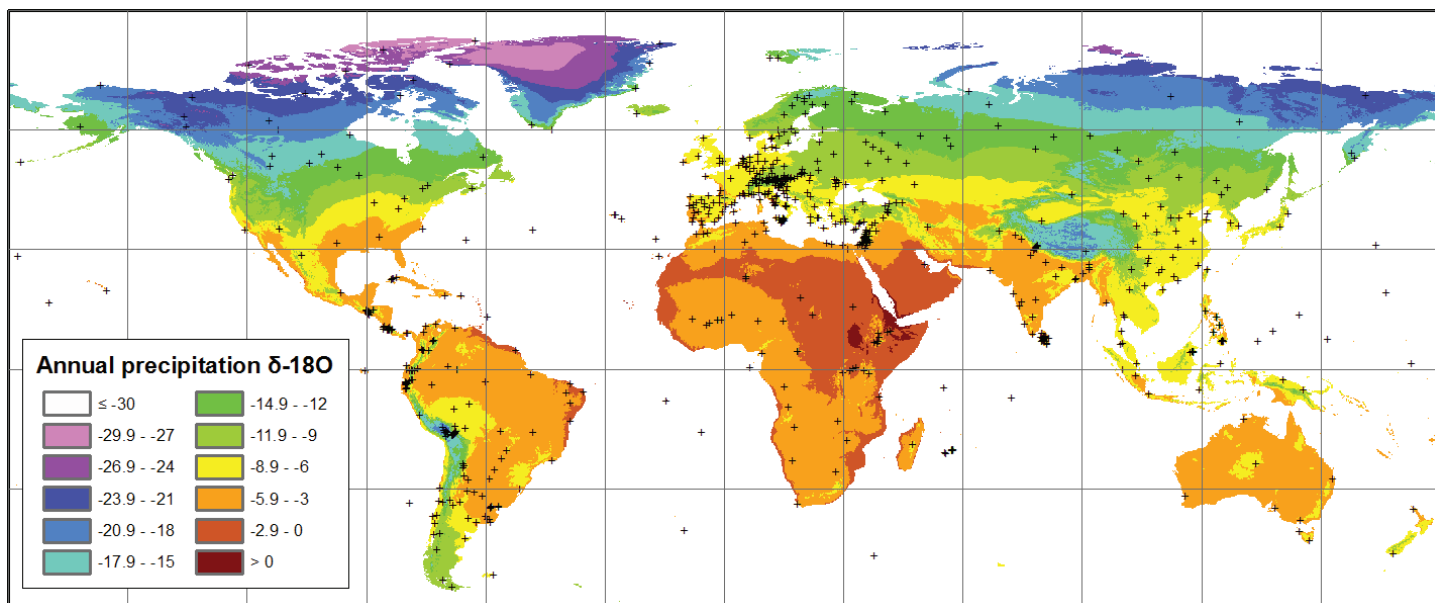
In 2012, a survey was distributed among the registered users of WISER, with the aim of getting a better understanding of the GNIP user community and the profile of regular users. The report is available upon request at gnip@iaea.org. The geographical distribution of the survey respondents revealed a dominance of users from the United States of America, followed quite closely by Germany, China, Spain, United Kingdom and Japan. Among the other top-ranked countries, all of them have a long-standing tradition in water isotope applications, not only in research and University centres, but also in institutes conducting applied research in hydrology and other fields.



Professional profile of the users of the GNIP database participating in the last GNIP/WISER survey.

Looking at the professional profile of the participants in the survey, however, it still becomes evident that the majority of the GNIP users are located in either academia or governmental organisations. This reflects the fact that, for the last decades, the isotope monitoring programmes and the analytical equipment required to conduct isotopic analyses were usually conducted or located in one of these types of institutions.

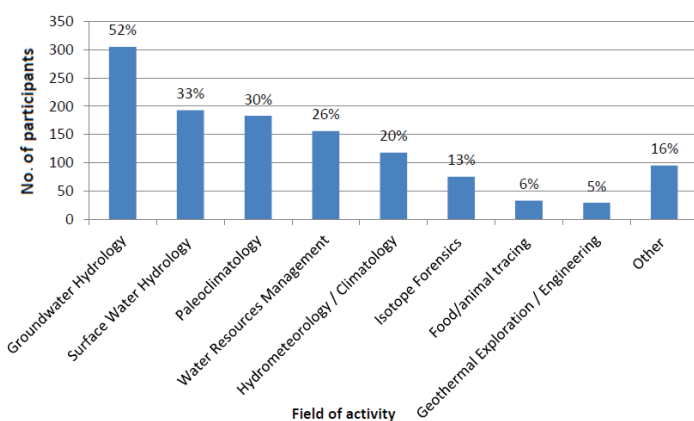
Though the majority of GNIP data users still stem from the 'traditional' hydrological community, the role of GNIP



Spatial distribution of long term $\delta^{18}O$ values in precipitation using data monitoring sites in the GNIIP database.

in providing basic input data is also well established in (paleo)climatology, making scientists from these communities key stakeholders of the GNIIP database. The IAEA gratefully acknowledges that a number of latest datasets incorporated into GNIIP originate from this kind of investigations. Isotopic tracing of migratory animals, food authentication and isotope forensics form the third important and growing part of GNIIP data users.

For further information, please contact Stefan Terzer at s.terzer@iaea.org



Most common environmental fields using the GNIIP database as reported during the last GNIIP/WISER survey.

Get Involved with GNIIP

The WRP has the mandate to expand and maintain the GNIIP network. Contributions on a voluntary basis are always welcome. If you have an interest in environmental water isotopes, or your institute already has a weather station, why not consider sampling precipitation water for GNIIP? The IAEA can provide support for the following aspects:

- Sampling consumables (QA/QC controlled bottles);
- Shipment of empty bottles and precipitation samples from/to Vienna (1 x per year);

- Analysis of the samples at the IAEA Isotope Hydrology Laboratory.
- Basic support to cooperating labs to improve analytical performance.

In addition to that, the IAEA Water Resources Programme can provide all the information required for setting up sampling, etc.

Feel free to e-mail the GNIIP contact point gnip@iaea.org or consult the WRP website at www.iaea.org/water.

Progress Being Made in Dating Very Old Groundwater Using Noble Gas Isotopes

The first results of Kr-81 and He-4 analyses in the northern portion of the Guarani aquifer in Brazil have been obtained. Similar work is currently being conducted in Argentina, Vietnam and Thailand.



Sampling in Thailand (photo: courtesy of the Department of Groundwater Resources, Thailand).

The adequate characterization of groundwater flow and transport in most aquifer systems remains a challenge, particularly for large and deep aquifers with limited hydrogeological information. Groundwater age is an important parameter that integrates aquifer recharge and flow dynamics and provides the ability to reliably constrain conceptual groundwater flow models.

The Water Resources Programme is collaborating with the Universidade Estadual Paulista (UNESP) in Brazil, two research centres in northern Argentina, the Centre for Nuclear Techniques in Vietnam and the Department of Groundwater Resources of Thailand to research old groundwater, i.e. water recharged more than 50 000 years ago, which is the age limit for radiocarbon. The aquifers under study include two sectors of the Guarani aquifer, the Mekong delta aquifer and the aquifers under the Bangkok metropolitan area. Long lived radionuclides and other tracers are being used to determine groundwater age in these areas. The reevaluation of previous hydrological studies in this area, often including ^2H , ^3H , ^{18}O , ^{13}C , ^{14}C and hydrochemistry, together with carbon-14 results obtained in new samples collected in deep boreholes, suggested that previous age estimates of groundwater need to be revised.

Krypton-81, a radioactive isotope on a gas noble with a half-life of 229 000 a, is suitable for groundwater dating, based on its lack of chemical reactivity, the fact that it is not produced in the aquifer matrix and due to new analytical developments allowing its measurement via Atom Trap Trace Analysis (ATTA). Krypton-81 measurements using ATTA are being made in cooperation with the Argonne National Laboratory, based in the United States of America.

Device to extract dissolved gases

As described in Water & Environment News (Issue 29, 2011), a device has been built to extract dissolved gases from flowing water samples to obtain sufficient ^{81}Kr for analysis. After completing extensive tests both in the lab and in the field, the extraction device has been used in Vietnam and a similar device has been developed and used in Brazil. About 10 μL of krypton, together with other major dissolved gas species (N_2 , O_2 , Ar, etc.), are collected in a sampling cylinder. The next step is to separate and purify the krypton out of the mixture of dissolved gases in the cylinder and subject it to analysis, thus uncovering groundwater residence time.

Noble gases are also being measured in these aquifers; these provide information on recharge temperatures, a useful

indication in the case of palaeowaters. Helium-4 is another age indicator of old groundwater, since it accumulates in groundwater.

Progress in Brazil and Argentina

In the northern part of the Guarani aquifer in Brazil, groundwater samples were collected along a groundwater flow path that runs from an the outcrop area in the east to the deeply confined section in the west, where the aquifer is up to about 1000 m deep. Present groundwater recharge occurs in outcrop areas, as indicated by the presence of tritium and ^{14}C , indicating modern recharge. Radiocarbon activities reach values below detection limits at relatively short distances (a few km) from the outcrop. The abundance of ^{81}Kr in samples free of ^{14}C decreases from 0.81 ± 0.11 (expressed as $(^{81}\text{Kr}/\text{Kr})_{\text{sample}} / (^{81}\text{Kr}/\text{Kr})_{\text{air}}$) in the east to 0.18 ± 0.03 in the western most sample. Groundwater ages in these samples are in the order of 566 ± 60 ka. Measured ^4He -excess is far above that expected from in-situ production rates in sandstone aquifers and overestimates the age by several orders of magnitude. Krypton-81 ages were used to calibrate the ^4He geochronometer. Similar work is being conducted in Argentina in the southern portion of the Guarani aquifer.

Work in Thailand

The Department of Groundwater Resources, Thailand is implementing a research project (RC THA-16879) on groundwater assessment in the Bangkok metropolitan area and Chiang Mai Basin using isotope techniques, particularly noble gas isotope tracers for age dating. A counterpart was assisted by an Isotope Hydrology Section staff member in the collection of samples for noble gas isotopes, other isotopes (^2H , ^3H , ^{18}O , ^{13}C , ^{14}C), CFCs and chemistry in the Bangkok area. There are eight main aquifers in the central plain with depths ranging from 50–600 meters and which are clearly separated from each other. Samples were collected from 15 monitoring wells representing the three most exploited groundwater aquifers, namely Phra Padaeng, Nakhon Luang, and Nontha Buri Aquifers, at approximate depths of 100 m, 150 m and 200 m, respectively. For noble gas isotopes, water samples in big copper tubes and gas samples in small copper tubes using a membrane contactor sampler were collected. Physico-chemical parameters (EC, pH, temperature) were measured in the field. The counterpart team was trained in sampling.

Vietnam project

Since late 2011, the IAEA has been working with researchers at the Centre for Nuclear Techniques in



Sampling of krypton-81 in Brazil (photo: IAEA).

Vietnam to better understand the dynamics of two deep groundwater aquifers in the Mekong Delta. Particular emphasis is being placed on accurately dating deep and old groundwater to define groundwater flow direction and transit time in order to evaluate aquifer recharge. Isotope analysis on samples collected during the first sampling campaign revealed that some wells are too old to be accurately dated using ^{14}C — this necessitates the use of an alternative tool that can date groundwater older than 100 000 years. A second sampling campaign was undertaken in Vietnam between 26 November and 1 December, 2012. Ten wells scattered within the Mekong Delta were visited, and sampling using Isotope Hydrology Laboratory (IHL) devices was successfully completed at all localities. Four hours are required to set up and sample at one site; the second sampling campaign in Vietnam was undoubtedly very productive. Currently, these steps are being carried out in collaboration with external laboratories. The IHL is now developing a system to separate and purify krypton from gas samples collected via this device in the field so that the IHL will have the capacity to process samples for ^{81}Kr analysis.



Sampling paraphernalia (photo: IAEA).

IWAVE Helping Improve National Water Resources Management



The 56th General Conference IWAVE side event featured speakers from each of the three pilot countries, as well as attendance by IAEA Director General Yukiya Amano (middle) and Deputy Director General, Department of Nuclear Sciences and Applications, Daud Mohamad (next in foreground) (photo: IAEA).

The Isotope Hydrology Section held a well-attended side event at the IAEA 56th General Conference highlighting the IAEA Water Availability Enhancement Project (IWAVE Project) and featuring guest speakers from each of the three pilot countries involved.

IAEA Director General Yukiya Amano and Deputy Director General of the Department of Nuclear Sciences and Applications, Mohamad Daud, were present at the event.

Water is related directly or indirectly to most of the Millennium Development Goals (MDGs) on poverty, food, health, education and environment, stated Isotope Hydrology Section Head Pradeep Aggarwal, who laid out the project goals at the side event. He added that this link has prompted some to say, “If we get water right, we can get all other pieces of sustainable development right”, and “What we can’t measure, we can’t manage.”

The need to assess and manage water has been expressed by many international organizations, including the 1977 UN Water Conference in Mar del Plata in Argentina, the 2007

IPCC Technical Paper VI, the 2009 United Nations World Water Development Report 3, and others, stated Aggarwal. The difficulty in defining water resources, in particular groundwater, is nothing new. The magazine *Nature* ran articles from the 1930s emphasizing the complicated issue of defining groundwater in the United Kingdom, while the lack of information in the United Kingdom was confirmed and lamented upon even earlier in a 1911 *Nature* article.

Aggarwal quoted Jay Famiglietti from the University of California Irvine, who stated: “we don’t really know how much water we have; we don’t have a detailed picture of our water environment; and we don’t do such a great job of measuring its storage and flows within it. How in the world have we let this happen?”

IWAVE evolution

These sentiments lie behind the evolution of IWAVE, meant to enable Member States in the development and evaluation of methods and approaches to identify and

The Isotope Hydrology IWAVE General Conference side event provided information on project development in the three pilot countries.



fill gaps in hydrological data and information. The three countries involved, Costa Rica, Oman and the Philippines, have been addressing their water issues with the help of IWAVE for the past few years and were able to offer some feedback at the side event.

“A large number of countries are interested in this kind of approach to water assessment; many others wanted to join. It has been implemented on a pilot scale so we can understand ourselves how best to implement it. These three different regions have different challenges, and different institutional setups,” said Aggarwal.

“This kind of comprehensive assessment is something we have not done and Member States have also not done. We are coordinating not only ourselves and other agencies, but the Member States themselves are learning from the experience so it can be implemented more widely.”

There are also many commonalities, though each project is different, says Aggarwal. “We would like to document the lessons so we can implement it widely through TC (the IAEA technical cooperation programme). All three countries have completed the first step of the process; identifying priority gaps. Work plans were developed for 2012 and beyond, and each country is implementing activities specifically

targeted to fill these gaps, including reconnaissance sampling campaigns for isotopes and chemistry in 2012. This is meant to provide information to lay the groundwork for optimization of hydrological monitoring networks, which will be tailored to national needs.

“IWAVE has been a catalyst to bring institutions together.” National capacities are strengthened and timely decision making, integrated research, policy management and water security are emphasized, he said.

Costa Rica

Costa Rican Director of Water, Ministry of Environment, Energy and Telecommunications Mr. Jose Miguel Zeledon Calderon stated in his presentation that Costa Rica must improve its knowledge of water resources, and increase scientific certainty, in order to address growing conflicts between competing users, including tourism, agriculture and urban domestic needs.

He pointed out institutional and technical gaps, ranging from a lack of understanding of the economic and ecological benefits of an integrated approach in the water sector by decision makers and legislators in Costa Rica, to insufficient understanding of surface and groundwater resources, their interaction with each other and ecosystems, the capability of water systems to respond to anthropogenic and natural processes and the impact on the resource of efficiency improvements.

In order to address these issues, a work plan through to 2014 has been put in place, including scheduled activities and training.

Costa Rica has 34 water sheds and a lot of water capital but must improve its knowledge of water resources and increase scientific certainty to avoid conflicts. The IWAVE project has been a catalyst to bring institutions together, said Calderon, and very significantly, national level gaps in hydrological understanding, data and information have been identified. The hope is that the project will enable a



Members of the Oman delegation admire a poster at the Isotope Hydrology IWAVE side event.

comprehensive assessment of national water resources, with integrated decision making based on hydrological understanding.

The Blue Agenda, developed in 2012 by the Ministry of Environment, Energy and Telecommunication, outlines the national approach to water resource management.

The Philippines

“A big help will be the scientific approach of IWAVE in addressing water problems which all agencies agree on,” said Mario Montejo, Secretary of the Department of Science and Technology in the Philippines. “Since gaps have been identified, we now have a bigger picture and more integrated approach.”

Montejo says, “Inadequate assessment limits abilities to understand and make (an) own water resources programme. It is important to have effective and efficient support for water resources. It is a priority for growth and production. Water is the basic need and right of every person.”

Despite the fact the country has great water resource potential, there is a scarcity due to a lack of urban planning, indiscriminate and rapid urban development, climate change, and a lack of water resources management, including investment, he says. Other challenges include an uneven distribution of water resources due to physiography and climate, population growth, emigration and inadequate water supply infrastructure, as well as fragmentation or overlapping of water resource institutions and authorities. An important milestone in the Philippine IWAVE project has been the development of a report by the Philippine National Water Resources board (NWRB) and the IAEA documenting gaps in hydrological understanding, data and information identified and proposing necessary actions to fill these gaps.

“... it goes beyond using nuclear technology... this plays a big part, but more than that is the scientific discipline. Using this approach makes a huge water resources programme doable,” says Montejo.

Oman

In Oman, freshwater exists only in the northern and southern ends of the country, and there are serious problems with brackish or saline water, said Ali Mohammed Al-Abri, from Oman’s Ministry of Regional Municipalities and Water Resources. The expansion of the agricultural sector has led to increasing demands for groundwater, while there has been a loss of major agricultural areas due to saline intrusion. The protection and sustainability of historically and culturally important aflaj — there are over 4000 of



Posters highlighting IWAVE activities.

these ancient hydrological and irrigation systems — is a challenge.

The 2011 partnership with IWAVE has led to the identification and defining of gaps, while 1000 samples were taken in the course of a reconnaissance sampling programme from both aflaj, springs and wells. These

are being analysed to determine a course of action. This is one part of a larger plan of action taken by the Government of Oman. The current IWAVE plan (2012–2014) includes targeting identified gaps with actions such as sampling and workshops

in data management training on advanced hydrology of springs and numerical modelling.

The IWAVE vision is to provide the next generation and countries with clean water, to create a collective state vision of water management that meets populations’ wants and needs, said Aggarwal. “One has to think outside of the water box.”

For further information, please contact P.K. Aggarwal at p.aggarwal@iaea.org

*‘Water is the basic need and right of every person.’
— Montejo*

Note

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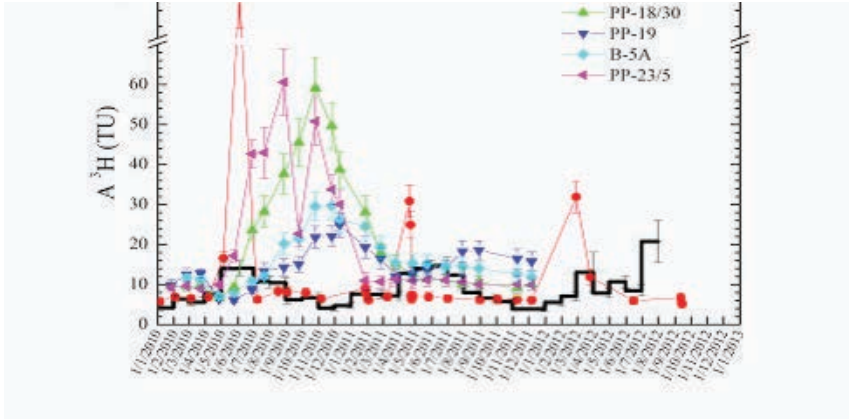
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Alternatively, it is also available on the website
<http://www.iaea.org/water>

Contributions to the newsletter are welcome.

Examining Riparian Drinking Water Resources in the Danube Basin

By Krisztina Kármán, József deák and István Fórizs (Hungary), Juraj Michalko and Radovan Černák (Slovakia), Nives Ogrinc (Slovenia), Nada Horvatinčić (Croatia), Nada Miljević (Serbia), Marin Ivanov (Bulgaria)



Field work in a multi-collector well, Szentendre Island, Hungary (photo: courtesy Istvan Forizs).

The importance of the need for high quality drinking water and for its long term secure supply is growing, even in economically medium developed countries. The drinking water requirements of several million people are covered by bank filtered (riparian) groundwater resources along the Danube River and its tributaries. These are very vulnerable water resources, of which exploited water is a mixture of waters coming from a minimum of two, but often from three or four sources as river water, locally infiltrated precipitation, distantly infiltrated precipitation, or infiltrated still water (from lakes or wetlands). The European Union (EU) Water Framework Directive (WFD) requires the setup of protected areas and management plans for groundwater bodies based on conceptual hydrological models. One of the most reliable methods for proving, calibrating or verifying these models is the application of environmental isotope data.

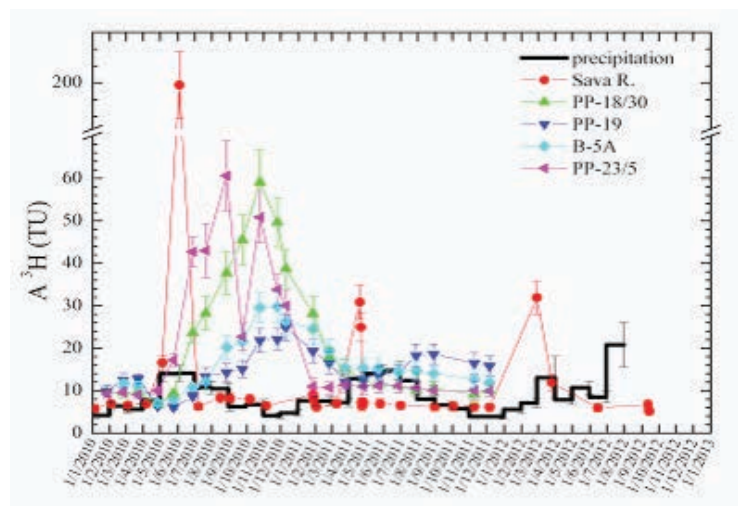
Projects in six countries

The ratio of filtered river water to background groundwater, the transit time of river water at different water levels, the age of distantly infiltrated water and the origin of nitrate and sulphate pollutions in the largest bank filtered water supply areas as well as some smaller areas have been studied via isotope methods. In total, seven study areas have been investigated in six countries: Slovakia, Hungary, Slovenia, Croatia, Serbia and Bulgaria. Although all these study areas

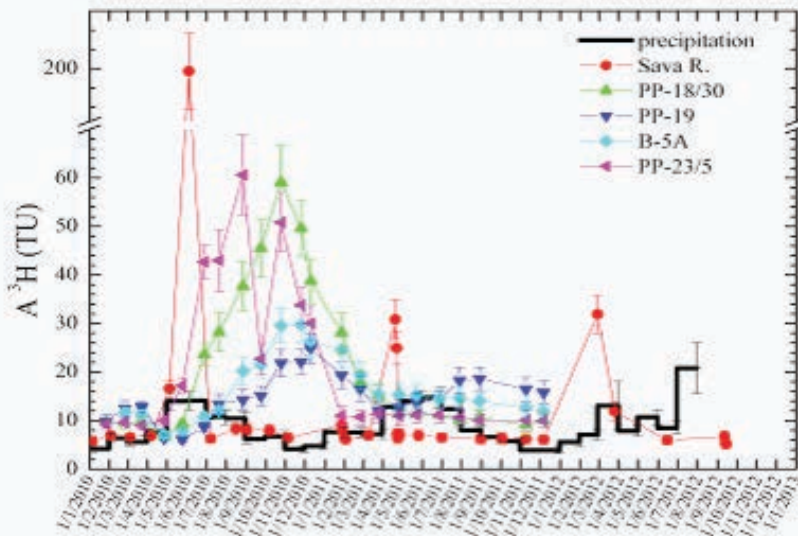
are riparian, there are characteristic differences between them. In some cases, river water transit time is only around two weeks, while in other cases it can take several decades. Previous studies carried out within the framework of international cooperation (in the upper Danube area: the Vienna basin, Szigetköz, and Budapest) proved that the isotopic composition of Danube river water differs significantly from background water recharging from local precipitation.

The application of isotope methods requires special knowledge both in the field and in the laboratory, so within the framework of the project a regional training course on planning and conducting fieldwork in isotope hydrology was held in the Belene Lowland, Bulgaria, primarily for young researchers who plan to

utilize environmental isotopes in their future work or who want to become acquainted with new isotope techniques. Two experts from Ireland and Hungary trained participants in how to take samples for common stable water isotopes (H, O) and radioactive isotope tritium, including radio-carbon age determination, and $^3\text{H}/^3\text{He}$ age determination.



Tritium activity in local precipitation, in the Sava River, and in several monitoring wells, Croatia.



Conceptual model of water infiltration from local precipitation and Danube River, Szentendre Island, Hungary.

Europe's biggest freshwater reservoir

The biggest fresh water reservoir of Europe is situated under the Little Lowland shared by Hungary and Slovakia, where the thickness of the gravel aquifer varies from a few meters to hundreds of meters. Water stable isotopes (H, O) and tritium data have proven that this aquifer is mainly replenished by the Danube River, where transit time is on the scale of decades. The 1963 bomb peak in the record of tritium content proved to be an excellent tool for determining the 3D groundwater flow system, including flow velocity and dispersion. In the Slovakian study area, stable oxygen and the sulphur isotopic composition of dissolved sulphate revealed a rather complicated origin of sulphate.

The Slovene capital, Ljubljana — as well as its surroundings — is supplied with drinking water exploited mostly from shallow aquifers. The origin of nitrate content in the most vulnerable aquifers has been revealed using dual isotopic composition (N and O). The results indicated that careful attention has to be paid to the agricultural use of nitrate containing chemical fertilizers.

The Sava River has a special stable isotopic characteristic. The isotopic water line of the Sava River is significantly above the local meteoric water line, providing an excellent tool to differentiate the origin of groundwater infiltrated from the river and precipitation in the Petruševac aquifer, which is used to supply the drinking water for Croatia's capital city, Zagreb. The Sava River's peak tritium record was caused by the planned release of tritiated water from the Krško Nuclear Power Plant (Croatia), making it possible to determine the dynamics of infiltrating riverine water.

Determining travel time

Determination of the actual travel time of river water to production wells was the goal of research in many study areas, such as Belgrade (capital of Serbia) and Budapest (capital of Hungary). The exceptionally frequent (daily) sampling of the Danube River and a production well on Szentendre Island (north of Budapest, Hungary) for water isotope measurements made it possible to determine the transit time of river water at high, medium and low riverine water levels, providing very precise and precious data for calibration of the hydraulic model of the flow system, and in this way improving security of the supply of high quality drinking water for more than 1.5 million people.

The Belene Lowland (Bulgaria), containing the Ramsar and Natura 2000 nature reserve areas, has proven to be the most complicated area. Groundwater originating from four sources (riverine, lake, local precipitation, and water infiltrated from nearby mountains) has been identified by means of applying environmental stable (H, O, C) and radioactive (tritium, radio-carbon) isotopes. This was the first application of environmental isotopes for hydrological purposes in Bulgaria, where results provided precious data for modelling the groundwater flow system of the Belene lowland and at the same time raised new questions to be answered in the future.

For further information, please contact Manzoor Choudhry at m.choudhry@iaea.org

The biggest fresh water reservoir of Europe is situated under the Little Lowland shared by Hungary and Slovakia...

News in Brief

IWBMiso developed by WRP

The Isotope Hydrology Section has developed a new isotope-enabled water balance model called IWBMiso. It is a monthly catchment water balance model tightly coupled with a monthly lake water balance model. It uses the inputs of monthly precipitation and monthly average maximum and minimum air temperature to compute runoff, evapotranspiration, and changes in lake, soil, subsurface, and groundwater storage components. In addition, it simulates the oxygen-18 (^{18}O) and hydrogen-2 (Deuterium, or ^2H) stable isotope composition of these storage and flux components.

Using measured isotope compositions of precipitation, rivers, lakes, and groundwater, an improved estimate of the magnitude of fluxes among the model components should be possible, or at least that is the premise. The major input for the simulation of stable isotope mass balance in the model is the isotope composition of precipitation that is mainly obtained from the IAEA GNIP database. The model is developed to use either freely available global climate datasets or locally measured station data. It will be made available for download cost-free through the IAEA web site. A number of pre-processing tools for data preparation will also be made available along with the model.

Departing staff members

- Manfred Jaklitsch retired from the Isotope Hydrology Laboratory (IHL) in December 2012 after 33 years of service. In his earlier days (1980s), he developed much of the equipment in the lab, including: a microprocessor-based electrolysis control unit; a microprocessor data acquisition unit for mass spectrometer MM602; an interface for connection of the Micromass ^{18}O equilibration line To Varian MAT250 mass spectrometer; software for the fully automatic operation of the mass spectrometer with the equilibration line; an advanced microprocessor-based data acquisition unit for Micromass MM602; hardware and software for the gas proportional counter system; and new head amplifiers with fiber optic link for the mass spectrometer.

Through the 1990s, Jaklitsch worked on the development of a 36-port hydrogen equilibration system; the installation of laboratory LAN to facilitate data transfer from instruments to the main database.

In 2000, the construction of 20-port vacuum distillation system for initial distillation of tritium samples took place, followed by the construction of a 48-port HDO equilibration line.

Manfred Jaklitsch was responsible for the upgrading, maintenance and repair of almost all laboratory equipment, as well as procurement, training of fellows, and other activities. During his career, Jaklitsch received several promotions, as well as merit awards in 1998, 2004 and 2008. His proficiency in English and Spanish was a great help in the over 30 TC expert missions he participated in, which took place in countries around the world.

- After three years with the Isotope Hydrology Section, Charles Dunning has returned to the US Geological Survey, Wisconsin Water Science Center, to continue various responsibilities including Groundwater Specialist and leader of the Resource Assessment and Ecohydrology Team. During his time with the section, Mr. Dunning was the Water Resources Advisor leading the IAEA Water Availability Enhancement Project (IWAVE project) the objective of which is to strengthen the capability of Member States to conduct comprehensive assessments of their water resources. Under his direction, the IWAVE project conducted pilot studies in three Member States — Philippines, Oman, and Costa Rica — to create and evaluate various methods, approaches, and templates for strengthening national capabilities to manage their own water resources.

- Michael van Duren has moved from the IHL to the IAEA Terrestrial Environment Laboratory in Seibersdorf, after serving as a laboratory technician since 2000.

- Maureen MacNeill joined the Isotope Hydrology Section as a consultant in June of 2008, and has been involved in an ongoing capacity in the organizing and planning of exhibitions for the section, including the annual European Geosciences Union, IAEA General Conferences (and Scientific Forum side events), symposiums and two World Water Forums. She produced promotional materials, such as brochures, postcards, posters, hands-on displays, videos, etc. for these activities. She also produced the section's bi-annual newsletter, worked on web page content and edited many technical books and other materials for the section.

Obituary

- The All-Russian Research Institute of Hydrogeology and Engineering Geology (VSEINGEO) lost its patriarch scientist Vladimir Dubinchuk in 2012. Mr. Dubinchuk made a great contribution to the development of isotopic investigations in the field of hydrology and worked for many years in the IAEA Isotope Hydrology Section.

Joel Gat: a pioneer isotope hydrologist 1926–2012



On 7 September 2012, Prof. Joel R. Gat (Munich, Germany, 1926–Rishon Le Zion, Israel, 2012) passed away after an illness discovered only a few weeks before. He was one of the most eminent specialists of isotope hydrology, the development of which he contributed to greatly.

Son of a German medical doctor, he left Germany

in 1936 with his family to emigrate to then Palestine, and eventually the State of Israel. He graduated in physical chemistry from the Hebrew University of Jerusalem, and in 1955 obtained a Ph.D. in isotope chemistry. He then spent two years at the University of Chicago with Prof. Harold Urey, where he came into contact with a group of young geochemists, among which Sam Epstein, Harmon Craig, Irving Friedman, and others who, together with Urey, founded and created the history of modern isotope geochemistry.

Joel Gat's first contribution to the IAEA programme was in 1961 when he was invited by Brian Payne — at that time head of the Isotope Hydrology Section — to take part with a dozen other experts in an Advisory Group Meeting in Vienna in order to define guidelines for the IAEA programme in isotope hydrology. After that time, Joel's collaboration with the IAEA remained uninterrupted. Many IAEA scientific and field projects benefitted from his deep knowledge of the isotope processes involved in the natural water cycle.

Joel Gat visited the IAEA two or three times per year — his last visit was in April 2012 — frequently accompanied by his wife Ileana, descendant of a Viennese family. It was always interesting and useful to hear Joel's viewpoints on recent developments and applications of isotope hydrology. He has been most influential in supporting IAEA programmes in this field, often playing a fundamental role in research programmes devoted to atmospheric water processes — evaporation, water vapour origin and movement, vapour condensation — and related stable isotope fractionations.

The scientific career of Joel Gat was almost entirely at the Weizmann Institute of Science in Rehovot, where he was head of the Isotope Department, and then Dean of

the Faculty of Chemistry. Thanks to him, the Weizmann Institute became, and still is, one of the major centers of isotope hydrology research in the world. With the death of Joel Gat, isotope hydrology has lost one of its most eminent protagonists. His sharp advice and expert accounts will be missed, as well as the memories of his long association with isotope science. Last but not least, we shall miss his jokes and humour, his rich and elegant language and his gentlemanly manners.

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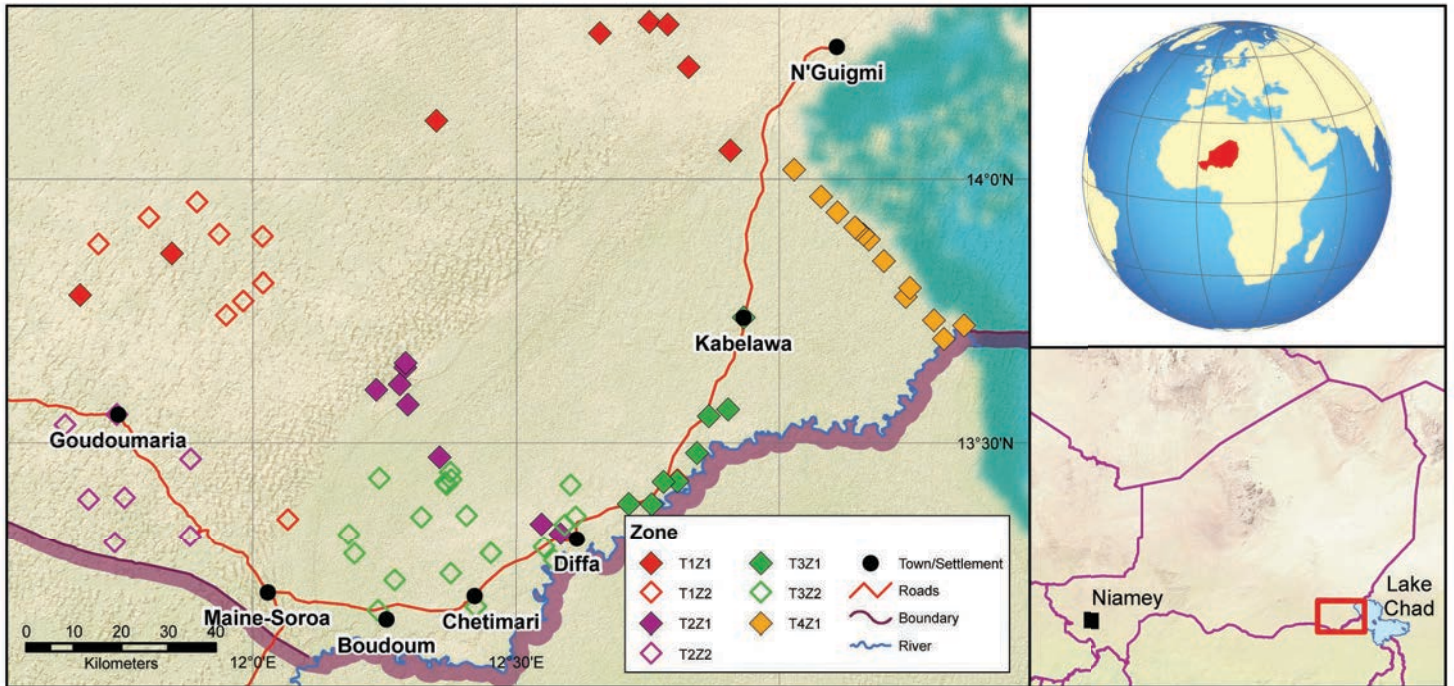
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Joel Gat (second left) with colleagues Peter Fritz, Louis Gordon and Roberto Gonfiantini (photo: IAEA).

Characterizing the Manga Aquifer to Ensure Safe Drinking Water in South-east Niger

By R. Sanoussi, A. Guéro (Ministère de l'hydraulique et de l'environnement; Direction des ressources en eau, Niamey, Niger), K. Zouari, R. Trabelsi (Université de Sfax, École nationale d'ingénieurs de Sfax, Département de génie géologique, Laboratoire de Radio-Analyse et environnement (LARA), Sfax, Tunisia), E. Gibert-Brunet (CNRS Ile-de-France Sud, Gif-sur-Yvette, France), M. Ito (IAEA)



Map of the studied region.

Increases in exploitation

Niger is the largest nation in West Africa (with 1.26 million km²), located between the Sahara and sub-Saharan regions without coast line. The majority of the country is covered by desert. Low precipitation (151 mm per year in 2009, World Bank 2010) and recurring droughts have made groundwater an essential water source. In the Diffa region (ca. 150 000 km²), located in south-eastern Niger and in the north-west of Lake Chad, groundwater is an important water source for the local population, together with surface water from Lake Chad and less importantly from the Komadougou Yobé River. A decreasing trend in rainfall, and hence shrinking of the area around Lake Chad, and irrigation development proposed by Nigerian authorities to meet growing food demand have led to actual and potential increases in groundwater exploitation. Moreover, water from Lake Chad has high salt content, limiting its usage. Groundwater resources in the region are found in several aquifer systems: (a) the Manga Quaternary aquifer covering nearly the entire Diffa region at 20 m to more than 50 m depth, except in a central part of the region (less than 10 m depth); (b) the alluvial aquifer located in the Komadougou valley and in topographic depressions

of the region at a shallow depth (less than 10 m); (c) the Pliocene aquifer in the Pliocene sands and silts, covering the entire region at about 300 m depth in most of the region or at about 200 m in the central part; (d) the Continental Intercalary/Hamadien aquifer, covering the entire region at 40 to 60 m depth with a very low or zero recharge rate.

To improve groundwater resource use and management of the potable water supply in the Diffa region, Technical



Water sampling in Niger.

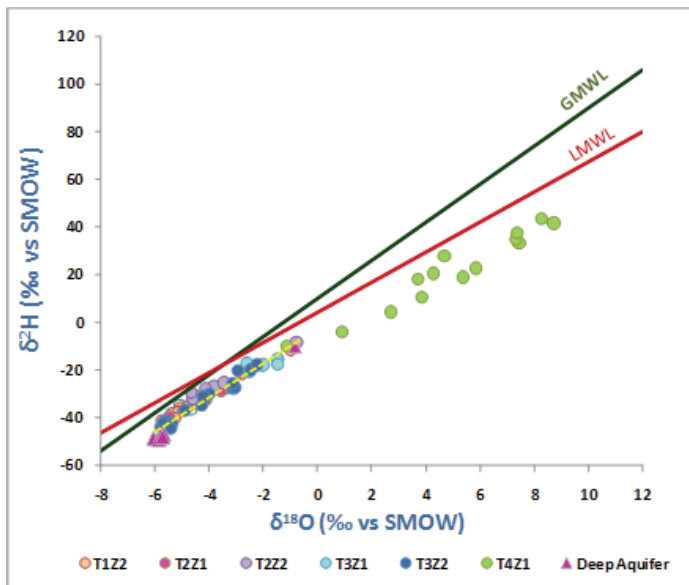


Diagram $\delta^{18}\text{O}$ vs $\delta^2\text{H}$ of analyzed groundwater samples in Niger.

Cooperation project NER8011 was conducted from 2009–2012 to characterize the Manga Quaternary aquifer system. The project was entitled Studying the Recharge Process and the Status of Mineral Deposits Within the Manga Aquifer (Diffa region). The project was implemented by le Ministère de L'Hydraulique et de l'Environnement, Direction des Ressources en Eau of Niger.

Stable isotope analyses

A total of 84 ground water samples were collected in August 2010 and June 2011 from seven zones (see figure previous page), including cemented wells (72), traditional wells (3) and operating (4) and artesian wells (5), in addition to rain and surface water samples. All water samples were analyzed for stable water isotopes (^2H , ^{18}O), tritium, major cations and anions, and some trace elements. Ten samples were also analyzed for $^{13}\text{C}/^{14}\text{C}$. An analysis of stable water isotopes showed that all groundwater samples collected in this study are below the Global and Local Meteoric Water Lines (GMWL and LMWL) (see figure above). The LMWL based on the precipitation data at the N'Djamena station has a slope ($\delta^2\text{H}/\delta^{18}\text{O}$) of 6.32.

The samples collected in five western zones (except for the north and east zones) had more negative values below and in parallel to the GMWL and the LMWL. Water in the western zones showed depleted $\delta^{18}\text{O}$ values (-5.35% vs. SMOW), below those of rainwater. Based on tritium values (> 1 UT), which suggest recent recharge, low $\delta^{18}\text{O}$ values are probably due to the altitude effect, not due to a paleoclimatic effect. The altitude effect could be explained by geological and geographical characteristics (the presence of massive Mounio granite in the west and the massive Termit Cretaceous in the north-west, and Agadem

and Koutous Cretaceous in the north and the west). The central zones also had depleted $\delta^{18}\text{O}$ values.

Recharge trends

The decreasing trend of $\delta^{18}\text{O}$ values with depth in these zones suggests the recharge of water from the deep Pliocene aquifer to the upper groundwater layers. The mixing of these groundwater sources is supported by piezometric measurements. The contribution of groundwater from the Pliocene aquifer water to the Quaternary aquifer in the central zones was estimated to vary from 10% to 79%, based on the binary equation presented by Clark and Fritz (1997) using the $\delta^{18}\text{O}$ values of water samples, the Pliocene aquifer water (mean: -6.3% ; Sabljak, 1998) and local rainwater (weighted average: -3.7% ; GNIP). Water samples in the east zone (the northwest to Lake Chad) had enriched $\delta^{18}\text{O}$ values (-1 to 8.7% , mean: 5%), suggesting an evaporation effect and the recharge of lake water. The contribution of lake water to the Quaternary aquifer in this zone was similarly estimated, using the $\delta^{18}\text{O}$ values of Lake Chad water (7.45% ; Sabljak, 1998) and rainwater (as above). The contribution of lake water in most sites is higher than 50% with 99% to 100% at five sampling sites adjacent to the lake, while the contribution was low or zero in other zones. Several samples in the central and southern zones at shallower depth also showed enriched $\delta^{18}\text{O}$ values (-3% to -2%), suggesting an evaporation effect and recharge by Komadougou Yobé river water. Estimated contributions of the river water, using the $\delta^{18}\text{O}$ values of Komadougou Yobé river water (-1.67% ; Sabljak, 1998) and rain water (as above), ranged between 3% and 42%, with higher contributions near the river.

The results of tritium (0.1–26.92 UT) and carbon-14 analyses as well as electric conductivity are also in good agreement with the contribution of Pliocene aquifer water and lake and river water, estimated based on stable water isotope analyses.

The residence time of water samples with very low tritium values was estimated using ^{14}C values with different models. Most samples were of modern recharge, but one sample in the western zone and another in the eastern zone were estimated to be more than 4000 and 8000 years old, respectively, based on the Evans model, the use of which was considered to be most appropriate. Hydrochemical and physical parameter analyses suggest that the Manga aquifer system contains several sub-aquifer sections with different geochemical facies, higher salinity was found in east zones and lower values near the river, but salinity source(s) may exist other than the lake. Fluoride was present in all samples, ranging from between 0.26 to 5.11 mg/L, many of which have higher concentrations than the WHO standard level (1.5 mg/L for temperate countries and 0.8 mg/L for tropical countries), and so on.

Under NER8009 and previous national and regional TC projects in Niger, project personnel were trained and have become capable of conducting hydrological assessments with the application of isotope and other techniques. Using the results of NER8009, a new study should continue to examine in more detail recharge processes and other interactions between various aquifers and other water bodies as well as to identify sources of highly dissolved minerals. The findings of these studies are expected to provide a good scientific basis for sustainable groundwater resource development and management in the region.

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Sixteen Countries Join in Training Workshop



Participants of a training course on Isotope Hydrology held in Addis Ababa, Ethiopia (photo: IAEA).

A three week international training workshop on isotope hydrology was jointly organized by the Ethiopian Water Technology Centre and the IAEA for African Countries at Addis Ababa, Ethiopia from 15 October to 2 November, 2012. The Japan International Cooperation Agency (JICA) worked as a local host organization on behalf of EWTEC in the organization of the training.

The training workshop was organized based on the Learning by Doing concept. Training was provided basically on three modules: basic concepts of isotopes including applications in hydrology and water resources; young groundwater dating and applications; and old groundwater dating and applications. In addition, a large number of hands-on training exercises and project work were assigned to participants and necessary guidance/assistance was provided to complete the tasks. A total of 31 participants from 16 African countries (Botswana, Cameroon, Ethiopia, Ghana, Kenya, Lesotho, Malawi, Mozambique, Nigeria, South Sudan, Sudan, Swaziland, Tanzania, Uganda,

Zambia and Zimbabwe) participated in the training workshop.

Lecturers included: Prof. Robert M. Kalin from Environmental Engineering for Sustainability, the David Livingstone Center for Sustainability, Glasgow, Scotland; Prof. Ing. Piotr Maloszewski, Institute of Groundwater Ecology, Helmholtz Center Munich-Neuherberg, Germany; Prof. Tenalem Ayenew and Dr. Seifu Kebede from the School of Earth Sciences, Addis Ababa University, Dr. Bhishm Kumar and Dr. Matsumoto Takuya from the IAEA, Vienna, Austria. The lecturers also assigned and helped in completing participant exercises and

project work and demonstrated field sampling of waters for isotope and chemical analyses. Dr. Pradeep Aggarwal, Isotope Hydrology Section Head, IAEA, participated in deliberations with senior Ethiopian government officials and JICA in Addis Ababa and participated in the closing ceremony.

The IAEA prepared comprehensive training material including: books, international seminars/symposia proceedings, IAEA TECDOCs, field sampling and laboratory analysis manuals, films, lecture notes and power point presentations of various experts/trainers and these were provided to each participant. The participants were very satisfied with the training material, as well as the quality of lectures, including hands-on training exercises and project work. EWTEC has requested the organization of such international training courses on alternate years, as it helps in demonstrating new technology to manage water resources, which are alarmingly undeveloped in many African countries.

LIMS launched

The IAEA and USGS are launching a new, co-developed Laboratory Information Management System for users of liquid water isotope laser absorption spectrographs entitled 'LIMS for Lasers'.

'LIMS for Lasers' is a cost free, Windows-based instrument and laboratory data management product aimed at the increasing numbers of users of off-axis (Los Gatos Research) or cavity ring-down (Picarro) laser absorption spectrographs (LAS), which measure the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of liquid water. 'LIMS for Lasers' assists laboratory staff by automating the laborious task of CSV data management, and difficult data corrections created by inter-sample carryover and instrumental drift.

Key features of 'LIMS for Lasers' include: A full client project data management and reporting system; proven laser sample analysis templates; automated between-sample memory correction; automated instrumental drift correction; automated outlier identification; automated normalization of data to the VSMOW-SLAP scales; tracking of My Lab QA/QC monitors instrument and laboratory performance; customizable Excel client

sample submission templates; and VSMOW/SLAP laboratory standard calibration templates.

User benefits include: Increased laboratory productivity by elimination of complex Excel data spreadsheets; improved long term LAS performance through standardized PIT approaches; reduction of laboratory error in client and data management; fast performance evaluations through One-Click QA/QC tracking; and 100% compatibility (and concurrent use) with LIMS for Light Isotopes v.9x for IRMS systems.

Laboratory implementation is undertaken via: Ready-made LAS instrumental databases allowing running of samples in hours; and a newly written, fully illustrated, how-to user manual with tutorials.

For more information and links see: http://www-naweb.iaea.org/napc/ih/IHS_resources_sampling.html#lims, or <http://isotopes.usgs.gov/research/topics/lims.html>

LIMS for Lasers training courses are offered through the IAEA in Vienna, and at other selected locations throughout the year.

Meetings in 2013

- CM on the use of radiogenic and stable isotopic tracers to assess groundwater transport in clay-rich, diffusion-dominated hydrological systems, Vienna, Austria, 4–6 November.
- 3rd RCM on isotope methods for assessing the impact of climate change on water resources in snow, glacier and permafrost dominated areas, Vienna, Austria, 18–22 November.
- 1st RCM on stable isotopes in precipitation and paleoclimatic archives in tropical areas to improve regional hydrological and climatic impact models, Vienna, Austria, 2–5 December.

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