Water & Environment News

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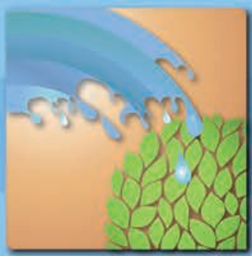
International Atomic Energy Agency



Newsletter of the Isotope Hydrology Section
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In this Issue

IAEA
Water Resources Programme

Sampling techniques for different isotopes have evolved over the more than five decades that isotope hydrology has been a science. The role of the Isotope Hydrology Laboratory (IHL) in measuring such samples and supporting Member States has evolved as well. See p. 11 (photos: IAEA).

From the Section Head

This edition of our bi-annual newsletter once again lists staff changes in the Isotope Hydrology Section. Nearly 80% of the staff has been with the IAEA for less than five years. Staff rotation with a limited tenure is an important aspect of the IAEA's employment policy, which mandates a balance in staffing with a 'long term' and a limited, 5–7 year tenure or 'tour of duty'. I am happy to note that qualified, energetic and motivated scientists from across the world (presently from 15 countries) continue to be interested in working at the IAEA for the short or long term.

Some of the historical developments in the field of isotope hydrology have been intertwined to some extent with the IAEA. A compilation of benchmark papers in isotope hydrology was recently completed and has been published by the International Association of Hydrologic Sciences. I hope that it will provide a useful and historical perspective on isotope hydrology for both students and professionals alike. Also in this edition is a perspective on the 50 year history of the IAEA isotope hydrology laboratory. The IAEA Water Availability Enhancement Project (IWAVE) — which aims to improve comprehensive assessments of water resources in three pilot countries — is making steady progress. A critical first step has been successfully completed with the identification and profiling of national gaps in hydrological data, information and understanding, as well as the expertise, technology and infrastructure support required in filling these gaps. Each pilot country is now implementing activities specifically targeted to fill its individual priority gaps and we hope that the conclusion of this project will help create a better scientific basis for policy support................ P. Aggarwal

Compilation of Benchmark Papers Released

Pieter Brueghel the Elder's painting 'A Gloomy Day', on the book's cover, exhibits part of the water cycle.

Isotope Hydrology uses stable and radioactive isotopes of water and its dissolved constituents to trace hydrological processes, including the pathways of rainfall and snowmelt to, and interactions between, aquifers, lakes and rivers. The potential of using stable isotopes of water was recognized in the 1930s, but not fully explored until the 1950s, since when the scope and nature of isotope applications in hydrology have blossomed. Improvements in measurement techniques have facilitated use of isotopes in many contexts, and isotope hydrology has become mainstream, as documented in this volume of reprinted papers and accompanying commentaries.

Section A. Fundamentals includes the first papers on deuterium, ^{18}O and tritium contents in natural waters (Friedman, 1953; Epstein and Mayeda, 1953; Libby, 1953) and Craig's (1961) seminal paper, which defined the global meteoric water line used to understand the source of natural waters. The papers that shaped our understanding of isotopes in precipitation and global circulation, e.g. Dansgaard (1964) and Craig and Gordon (1965), come in B. Atmospheric Water Cycle. The early interpretation of isotope sequences in rock and ice, including the iconic Greenland ice sheet core (Dansgaard et al., 1969), are included in C. Palaeoclimates. D. River and Lake Hydrology contains influential papers on the use of isotopes to determine the origin of stream and lake waters. E. Groundwater deals with the origin of groundwaters, the earliest use of tritium, ^{14}C, ^{81}Kr and ^{36}Cl to date them, and isotope applications in pollution and groundwater remediation.

The book is an excellent resource for graduate and post-graduate level courses in hydrology, reproducing many important papers which are otherwise difficult to access.

The co-authors have been involved with isotope hydrology for most of their professional lives while working with or for the IAEA. Pradeep Aggarwal, Head of the Isotope Hydrology Section since 1999, came to the IAEA from Argonne National Laboratory, USA. Klaus Froehlich came to the IAEA in 1988 from the Institute of Physics, Freiberg University, Germany, and was Section Head from 1994 to 1999. He was preceded by Roberto Gonfiantini (1988-1993) who moved to the IAEA in 1970 from the University of Pisa, Italy. Joel Gat began his work with isotope applications in hydrology in the late 1950s while at the Weizmann Institute of Science in Israel, and has been associated with the IAEA ever since.

The book was published by the International Association of Hydrological Sciences (IAHS) in cooperation with the Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA) of the University of Arizona, as part of the IAHS series on Benchmark Papers in Hydrology.

Significant articles

The book reproduces in their original form 34 scientific articles which determined the history of isotope hydrology — many others are discussed, but unfortunately were not possible to reproduce due to space limitations. The following criteria were used to select or exclude topics or papers in this compilation:

1. The benchmark papers should deal directly with, or provide information on, aspects of the hydrological cycle. This led to the exclusion of papers having essentially physical or chemical objectives, such as the determination of fractionation factors of stable isotopes or the half-life of radioactive isotopes, or the quantum-mechanical theory of isotope fractionation.

2. The quality of data should be adequate and valid for reference and use in modern investigations, and for quotation in modern papers. This led to the exclusion of papers published from the discovery of oxygen and

hydrogen isotopes (1929–1931) until the end of WWII, when analytical methods were still inadequate and led only to vaguely outline some of the isotopic variations taking place in the hydrologic cycle.

3. Papers dealing with the development of analytical instruments and methods — although essential for the progress of isotope sciences in general, including isotope hydrology and geochemistry — have been excluded. Also papers dealing with isotope reference materials — often prepared directly by or with the support of the IAEA — have not been included. The book in fact is addressed to hydrologists who know how to use analytical instruments and methods, but usually do not develop them (through many exceptions exist).

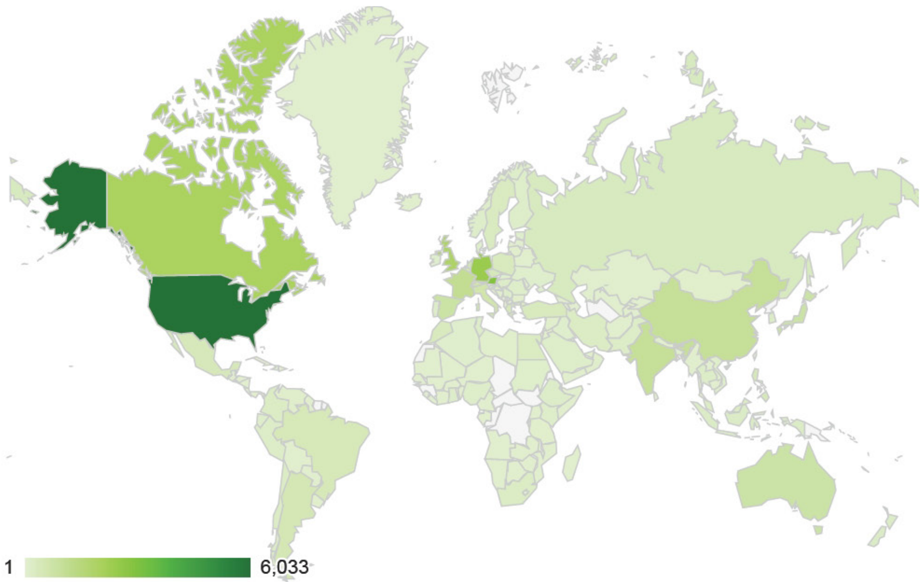
4. Papers dealing with geothermal waters were not included, in spite of the role of stable isotopes in understanding the geochemistry of hydrothermal systems, and in particular in studying water–rock interactions at high temperature. Such papers would be better placed in a volume devoted to hydrothermal systems.

Brueghel and Hydrology

Illustrating isotope hydrology is not easy, so the upper part of the 1565 painting by Peiter Brueghel (facing page top) was chosen by Pradeep Aggarwal and colleagues for the front cover of the newest volume in the IAHS Benchmark Papers in Hydrology Series, Isotope Hydrology. The painting, titled 'A Gloomy Day', belongs to the Kunsthistorisches Museum in Vienna, Austria.

A final remark about the book cover image, from Roberto Gonfiantini: "The atmospheric cycle of water, including clouds above the sea, and precipitation and snow accumulation in mountain glaciers, is represented in this four and a half century old painting. The processes in the atmosphere result in the isotopic fractionations of water, and the interpretation of these isotopes widely contributes to the understanding of the whole cycle of water."

Visits to Isotope Hydrology Website on the Rise



Visits	Pages / Visit	Avg. Visit Duration	% New Visits	Bounce Rate
32,065	**2.71**	**00:03:13**	**58.23%**	**55.38%**
% of Total: 100.00% **(32,065)**	Site Avg: 2.71 **(0.00%)**	Site Avg: 00:03:13 **(0.00%)**	Site Avg: 58.23% **(0.00%)**	Site Avg: 55.38% **(0.00%)**

Statistics show the Water Resources Programme website has drawn 32 065 visits in the one year period between 1 July 2011 and 31 July 2012. The section released a new webpage design in 2010.

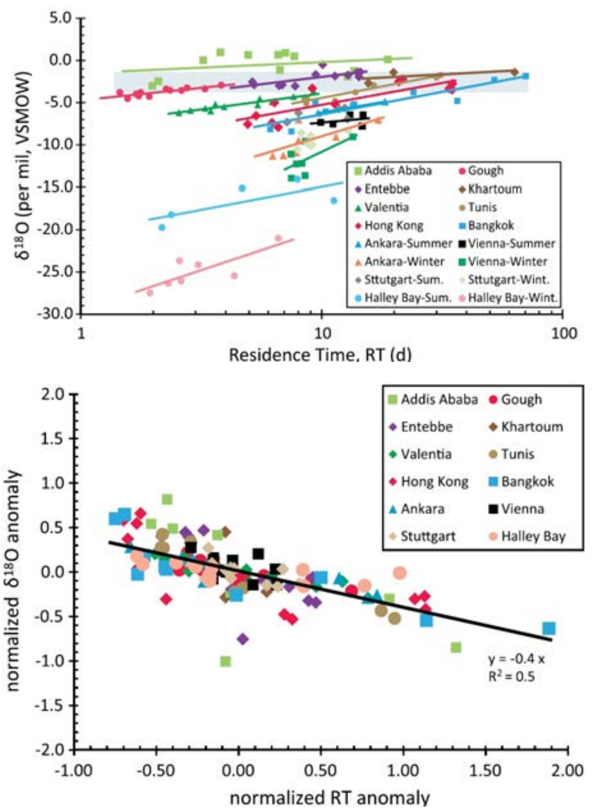
Despite parts of the site not functioning completely in 2012 due to a renovation project involving the Programme's isotope databases (including all graphical user interfaces, particularly WISER, which serves a 'window' to our data customers), numbers remained high, jumping from the 17 732 visits which took place between 1 January and 31 December 2010, the time in which the website transition was taking place. When broken down by country, the United States of America topped the number of visits, with Austria, Germany, Canada and United Kingdom following in that order. In sixth place came France, followed by India, China, Spain and Australia.

The designations employed and the presentation of material in this map do not imply the expression of any opinion whatsoever on the part of the Secretariats of the International Atomic Energy Agency and of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

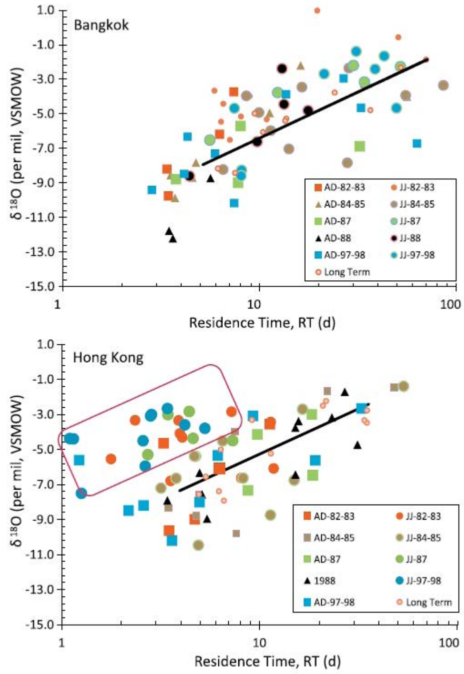
New Approach Presented to Interpret Precipitation Stable Isotope Ratio Variations

A paper entitled Stable Isotopes in Global Precipitation: A Unified Interpretation Based on Atmospheric Moisture Residence Time, and authored by Isotope Hydrology Section Head Pradeep Aggarwal, along with colleagues (Oleg Alduchov, Klaus Froehlich, Luis Araguas-Araguas, Neil Sturchio and Naoyuki Kurita) has recently been published in *Geophysical Research Letters*, Vol. **39,** L11705 (2012).

The abstract of the paper states: "We present a new approach based on atmospheric moisture residence time (RT) to interpret precipitation stable isotope ratio variations in all climate regimes, including tropical and polar, on monthly or inter-annual time scales. δ^{18}O and ln RT are positively correlated and a single regression line describes variations in δ^{18}O and RT anomalies, overcoming limitations of existing Rayleigh distillation based approaches for tracing moisture dynamics and precipitation processes. We use this approach to characterize changes in tropical precipitation during El Nino events and suggest that increased precipitation in a warmer climate may occur with higher δ^{18}O values, contrary to assumptions made in interpreting proxy climate records in speleothems and other archives. Our results will allow the use of isotopes to monitor climate change impacts on the character and intensity of precipitation and to improve the performance of climate models by providing a direct means to calibrate model results."



(Above) Long term monthly average δ^{18}O of precipitation and total precipitable water. Dashed curves show isotopic evolution by Rayleigh distillation in equilibrium with ocean water, with initial Q amounts of 25 and 55 mm. (Below) Normalized RT and δ^{18}O anomalies with respect to annual or seasonal (summer or winter) averages. Seasonal averages were used for Ankara, Stuttgart, Vienna and Halley Bay, as in the above figure.



The δ^{18}O and RT variations in monthly precipitation at Bangkok and Hong Kong during El Nino (1982, 1983, 1987, 1997, 1998) and La Nina (1984, 1985, 1988) events. Long term monthly averages and their regression line are shown for reference. (graphs/abstract reproduced by permission of the American Geophysical Union; published by the American Geophysical Union (2012)).

Note

To receive a free copy of Water & Environment News regularly, please write to:

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Contributions to the newsletter are welcome.

The IAEA Water Availability Enhancement Project in 2012

Each IWAVE Project pilot country will undertake a reconaissance mission in 2012 to begin to build up a monitoring system. The first reconaissance mission will clarify what monitoring techniques are best implemented for specific areas.

Philippine scientists collect water samples in 2012 as part of an initial reconaissance mission to build up a monitoring network as part of the IWAVE Project (photo: IAEA).

The IAEA Water Availability Enhancement Project (IWAVE Project) has been undertaken to assist Member States in identifying and filling gaps in hydrological data, information, and understanding that are hindering their ability to conduct comprehensive water resource assessments. Such gaps are particularly acute with respect to groundwater resources, which represent the greatest potential additional source of recoverable fresh water in most Member States.

Methods and approaches to assist Member States in identifying and filling these gaps are being developed and evaluated through pilot studies being conducted in the Philippines, Oman, and Costa Rica. A critical first step has been successfully completed by all three pilot studies; that is the identification and profiling of national level gaps in hydrological data, information and understanding. The expertise, technology and infrastructure support required to fill priority gaps has been identified and work plans have been developed for 2012 and beyond. With this first step completed, each pilot study is now implementing activities specifically targeted to fill their individual priority gaps. By filling the gaps in hydrological data, information and understanding and by strengthening the capacity of Member States to conduct comprehensive assessments, the availability of fresh water in these countries will be enhanced. Fully realized comprehensive assessments conducted by Member States would quantify water quality, water quantity, and water use as well as resource vulnerability and sustainability.

Common gaps

While the hydrologic setting and institutional structure of the three pilot study countries is markedly different, it has been found that all three share some common gaps in hydrological data and information which limit the understanding of their water resources. Specifically, each pilot study has identified the following as priority gaps:

1. Fundamental data which underlie hydrological understanding is inadequate because:

- National approaches to data, such as monitoring networks, have not been established, or
- National monitoring networks do exist but are in need of evaluation and optimization.

2. Isotope hydrology and water chemistry approaches to understanding hydrological systems have generally been underutilized.

3. Management and sharing of data at the national level needs to be improved to support current and future resource management.

These common priority gaps have led all three pilot studies to undertake some similar activities in 2012, including the provision of:

- Guidance and training in the evaluation and design or optimization of hydrological monitoring networks;
- Training and support for national reconnaissance sampling programmes for chemistry and isotopes in

water, and the interpretation of these data;

- Evaluation of and improvement in the interagency sharing and management aspects of national hydrological data systems.

Distinctly different gaps

Pilot studies have also identified distinctly different gaps requiring country specific activities, including:

Philippines

- Training to fill priority gaps in surface–water data and information with a focus on estimating flow in gauged and ungauged basins;
- Field training and workshop to introduce appropriately advanced surface and borehole geophysical techniques applied to hydrogeological studies, including data collection techniques, processing, and interpretation;
- Advanced training to: quantify recharge to groundwater, integrate and interpret hydrogeological data and ensure the full application of isotope hydrology techniques in groundwater resource assessment.

Oman

- Training provided by IAEA in conducting field sampling operations;
- Training in the advanced assessment of groundwater resources through interpretation of hydrological, physical, and isotope data;
- Two week workshop on the hydrology of important discharge features in Oman including: advanced training in spring and wadi hydrology; numerical modelling of groundwater/surface water interaction and investigation of offshore discharge.

Costa Rica

- Support for development of the Costa Rican Agenda for Water, a framework to strengthen and maintain the necessary capacity for conducting comprehensive assessments for the management and sustainability of Costa Rica's water resources;
- Training in hydrogeological mapping using appropriately advanced classical and isotopic techniques;
- Training in advanced mathematical modelling in order to simulate: the interaction of surface and groundwater and groundwater flow and contaminant transport and flood risk.

For further information, please contact Chuck Dunning at c.dunning@iaea.org

Isotopic Methods for Dating Old Groundwater

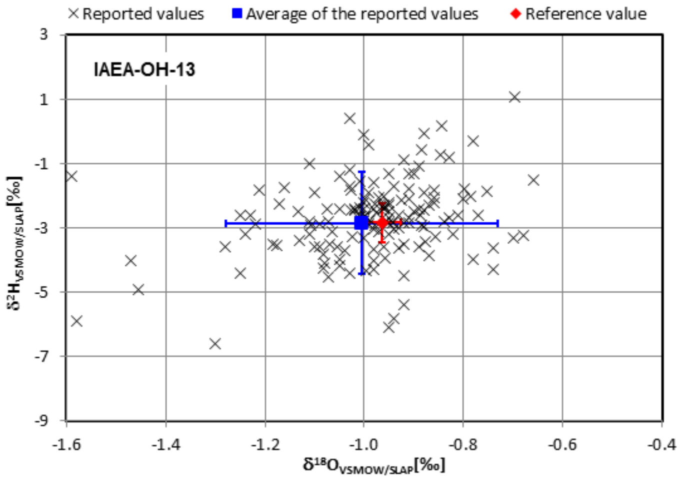
The IAEA will soon be releasing a book entitled Dating Old Groundwater: A Guidebook.

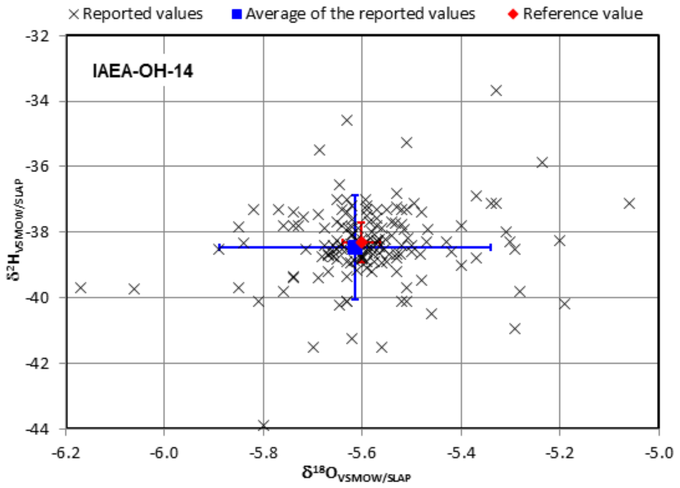
In many parts of the world, groundwater constitutes the major source of water for agriculture, energy, industry and urban use and it is expected to play an even greater role in the next decades. The rising importance of groundwater is a result of increasing water demands deriving from population growth and concerns about the impact of predicted climate change on the hydrological cycle. Unfortunately, in many cases, water officials and managers lack the knowledge of local groundwater resources required to ensure adequate and long term access to available water resources.

New scientific, technical, social and legal questions and a growing number of conflicts and issues on water usage require a better understanding of the movement, origin, and age of groundwater. For several decades, isotope tools have been one of the main tools to obtain information about groundwater origin, its properties and movement, often providing insights not available through other techniques. Information on groundwater age is required to address aspects such as recharge rates and mechanisms, resource renewability, flow rate estimation in aquifers or vulnerability to pollution, especially when dealing with shared water resources. Age information, mainly provided by radionuclides and modelling, is considered highly relevant to validate conceptual flow models of groundwater systems, calibrate numerical flow models and predict the fate of pollutants in aquifers. Isotope tracers are now used to study groundwater age and movement covering time spans from a few months up to a million years.

The understanding of groundwater occurrence and movement in large continental basins has been a matter of debate among experts. Despite the large number of studies which have been carried out in the past, many open questions remain and ideas and concepts are often revised based on new conceptual models, isotope and tracer analyses or water flow models. This publication is presented in the form of a guidebook, with 13 chapters explaining what is currently understood about the use and application of radionuclides and related geochemical tracers and tools to assess groundwater age and movement in time spans beyond a few thousand years.

WICO Report/Article Released





$\delta^2H/\delta^{18}O$ plot of all reported laboratory mean values for samples IAEA-OH-13 and IAEA-OH-14 compared to the assigned reference values. Not all values could be displayed using the selected scale.

The final report on the fourth interlaboratory comparison exercise for δ^2H and δ^{18}O analysis of water samples (WICO 2011) report is now available for download on the isotope hydrology website, at http://www.iaea.org/water. A research article on WICO has also been released, entitled Worldwide Proficiency Test for Routine Analysis of δ^2H and δ^{18}O in Water by Isotope-Ratio Mass Spectrometry and Laser Absorption, *Rapid Commun. Mass Spectrom.* 2012, **26**, 1641–1648. Both the report and the paper reached similar conclusions, including that: A worldwide proficiency test of laboratory returns for the analysis of δ^2H (160 sets) and δ^{18}O (167 sets) values in four test water samples using LAS or IRMS technology showed >90% were within acceptable tolerance limits, falling within 2% for δ^2H values and 0.2% for δ^{18}O values of the established reference values for the proficiency test waters. Three main factors seemed to be behind questionable or poor performance.

Improper calibration or storage of primary reference waters or secondary laboratory working standards appears to be the main cause of outliers. Careful calibration of laboratory working standards annually using the new VSMOW2/SLAP2 primary standards by individual labs, and scrutinization of the isotopic integrity of primary reference and daily use water lab standards would be useful. Evaporated or contaminated standards will result in systematic off-sets.

As well, it has become clear that daily routine calibration using only one internal laboratory standard cannot be used to correct for any scale normalization effect. Labs should use two isotopically separate laboratory standards encompassing the isotopic range of unknown water samples for each autorun to allow for scale normalization; these should have been previously carefully calibrated to the VSMOW/SLAP scale. In this exercise, seven laboratories used only one calibration to normalize their unknown results. This practice has been strongly discouraged for some time, and remains so regardless of the analysis technology that is used. The best results can be ensured through appropriately bracketed data normalization, which also corrects instrument specific scale expansion or contraction effects, irregardless of the severity of this scale effect.

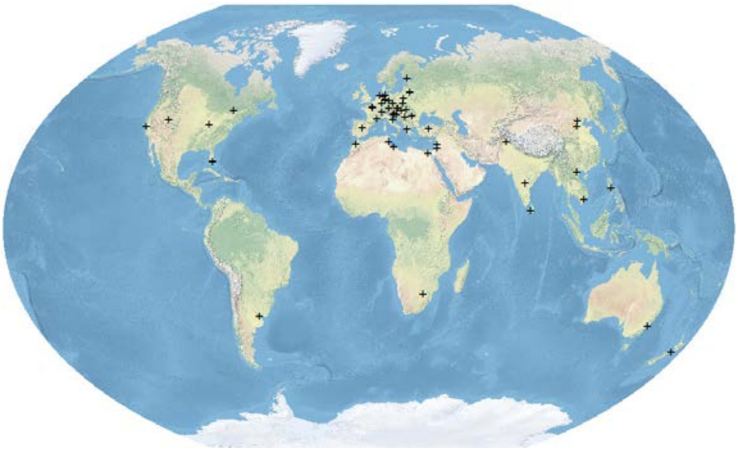
It is further recommended that laboratories carefully track their QA/QC, and work on documenting and reporting realistic precisions for their δ^2H and δ^{18}O results in order to offer realistic performance metrics to their clients. The use and monitoring of independent control water standards (not used to normalize sample results) is strongly recommended to obtain this information. Few participating labs reported long term precisions, and those that did provided scant information on how long term precision was defined or determined.

For LAS-based labs, lack of clarity on how laboratories quantified instrumental drift and inter-sample carryover effects constituted another QA concern. LAS-based analytical outcomes can be improved in the future through adoption of standardized analysis templates and documented approaches to quantify and correct for these effects.

The tools required to assess and quantify LAS drift and inter-sample memory effects are available for free on the IAEA website and in LIMS. This study very positively showed that most labs produced acceptable results for the purposes of routine hydrologic applications, regardless of the type of measurement technology used.

Laser absorption spectroscopy technology continues to be rapidly adopted into many laboratories and this trend seems set to continue in the future. The machines may eventually replace traditional isotope-ratio mass spectrometry as the technology of choice for routine measurements of the δ^2H and δ^{18}O composition of natural waters.

Isotope Hydrology Laboratory News



Sixty-three laboratories (above) from 37 Member States were involved in tritium measurement inter-comparisons in TRIC 2008.

Tritium inter-comparison

Reliable age determinations provide critical information for planning sustainable exploitation of available groundwater resources, and for developing new water supplies. Tritium and tritium/helium are critical isotopic tools used to reliably quantify the age of waters that have replenished aquifers over the past six decades.

The IAEA previously conducted eight tritium measurement inter-comparisons (TRIC) involving 37 countries worldwide (see map) in order to enhance worldwide laboratory data comparability and reliability, as well to promote improved standardization of methods and outcomes.

The TRIC 2012 inter-comparison will involve the preparation and distribution of six test samples of widely differing tritium content, prepared at the IAEA through the dilution of a high concentration tritium measurement standard. Results will be returned to IAEA for assessment and a final published summary and synthesis report. Confidential proficiency reports will be provided to each participating laboratory to help assess and improve their performance.

Test samples for the 9th tritium interlaboratory comparison are being prepared during the summer of 2012, and will be followed by a formal TRIC 2012 announcement and sample shipment to participants in the autumn.

For further information, please contact Darren Hillegonds at d.hillegonds@iaea.org

Secondary isotope standards

Surface and groundwater samples have been collected from Puerto Rico and Alberta, Canada, spanning the most common high and low isotopic range encountered in stable isotope analysis. Some 35 gallon samples were collected this spring by our partners; they are currently being characterized for isotope comparison and packed into ampoules in cooperation with the USGS lab in Reston, USA. Approximately 60 000 4 mL ampoules will be made available in 144 ampoule boxes — a one year supply of two lab standards for daily use — to Member State labs both by the IAEA and the USGS.

The project was undertaken in response to the WICO conclusions that poor lab results stem from inadequate lab standards and handling issues. With only a few millilitres of the primary reference material (VSMOW/SLAP) available every three years, it has been difficult for many laboratories to get good standards for daily use, especially in developing countries.

The new LIMS for Lasers software (see article below) will use these new lab standards in default analysis templates, to further improve reliability of outcomes in new labs.

It is to be noted that these are not primary reference materials, (nor are they intended to replace VSMOW/SLAP) but rather top quality secondary standards, so the onus is still on laboratories to calibrate their instruments.

LIMS improving quality assurance

The Isotope Hydrology Laboratory (IHL) has partnered with the USGS to develop a Laboratory Information Management System (LIMS) for light stable isotopes specifically for data produced by laser absorption spectroscopy (LAS) in order to improve global performance and trustworthiness of laser-based isotopic results.

Over the past few years, LAS has revolutionized the analysis of stable isotopes of water; the inexpensive, user friendly, high precision instruments require little maintenance or technical skill to operate. LAS is quickly becoming the foremost method for measuring δ^2H and $\delta^{18}O$ in rain, surface water and groundwater, especially in new laboratories and in developing countries. However, although LAS instrumentation is very easy to use, the raw isotope data from these instruments has not been as easy to work with. In the past, the effects of inter sample memory, uncontrolled instrumental drift, overwhelming volumes of CSV data, and improper normalization of the results have not only made data analysis difficult for users, but has led to inconsistent outcomes.

These problems are largely overcome by using LIMS for Lasers, which has the effect of improving quality assurance, increasing laboratory efficiency, reducing processing workload and decreasing lab errors. LIMS for Lasers is a user optimized version of the USGS LIMS for Light

Isotopes system applicable only for laser-based analysis of stable isotopes of water (oxygen and hydrogen), and is meant to make data handling and information processing easier for Member States using LAS machines. In addition, the documented track record of laboratory performance provided by LIMS provides an audit and assistance trail.

The IHL is in the process of testing LIMS for Lasers, which will be made available cost-free on the IAEA and USGS websites. LIMS for Lasers includes: a simplified interface for LAS instruments, full client, project and data management system, LAS optimized analysis templates, automatic LAS sample list generation and data import, automatic LAS memory and drift correction, full data normalization and performance monitoring over time. *For further information, please contact Len Wassenaar at l.wassenaar@iaea.org*

RCM Discusses Isotope Studies of Snow, Glacier and Permafrost Under Climate Change

Participants of the RCM, held in Vienna, Austria (photo: IAEA).

The 2nd Research Coordination Meeting of the CRP on Use of Environmental Isotopes in Assessing Water Resources in Snow, Glacier, and Permafrost Dominated Areas under Changing Climatic Conditions was held at IAEA Headquarters in Vienna, Austria from 18–21 June 2012. Counterparts/representatives of research groups from Argentina, Canada, Georgia, Italy, Japan, Morocco, Pakistan, the Russian Federation, Slovakia, Slovenia and the United States of America participated in the meeting. This CRP was started in 2010 to test the use of isotope techniques for the assessment of snowpack, glaciers and permafrost in groundwater and surface water systems. It is aimed at assembling isotopic evidence for water derived from snowpack, glaciers, and permafrost, and at the isotope supported estimation of transit times of meltwater through snow and ice layers, residence times in the subsurface and travel times to rivers and lakes as well as water supply and water energy facilities. The methodologies used in the CRP will be assessed for their applicability to different catchments, particularly under changing climate conditions.

The participants had used some common methods across different spatial and temporal scales and discussed problems encountered when using these methods. Preliminary efforts were made towards the standardization of common methodologies and sampling designs, which will be further refined. Participants made significant progress on the following objectives:

1. Quantifying the contribution of snow, glaciers and permafrost to the water budget of streams (Georgia, Italy, Japan, Pakistan, Slovakia, Slovenia and USA);
2. Quantifying the contribution of snow, glaciers and permafrost to groundwater recharge (Argentina, Canada, Georgia, Italy, Morocco, Pakistan, Slovakia, Slovenia);
3. Providing more qualitative information to refine conceptual models concerning the role of snow, glaciers, and permafrost to the water budget of a catchment (Argentina, Canada, Japan, Morocco, Slovenia);
4. Improving characterization of the isotopic composition of different components of the cryosphere (i.e. snowmelt, permafrost, glacier melt) (Canada, Georgia, Italy, Japan, Russia, Slovakia, Slovenia, USA).

Proposed further research

Many common themes are being considered, with considerable overlap in methods and approaches to be applied across different spatial and temporal scales. The preliminary results from this CRP have already contributed to improving the characterization of the isotopic composition and contribution of components of the cryosphere to the hydrological cycle, and have improved insight into the spatial and temporal variability of the isotopic composition of snowmelt. It was recognized that more work needs to be undertaken in a few areas; thus the development of a few additional coordinated activities designed to address some of the challenges common to all participants were agreed upon, including: creation of a pilot study to evaluate the spatial variability of snowmelt sampled by the passive capillary sampler (all participants); research on the mean transit time of snowmelt to streams (USA, Slovakia); and evaluation of existing data on the isotopic composition of permafrost.

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

Tritium–Helium-3 Dating Technique Examined

Participants of the 2nd RCM of Estimation of Groundwater Recharge by Using Tritium-Helium-3 Dating Technique (photo: IAEA).

The 2nd research coordination meeting (RCM) of the Coordinated Research Project entitled Estimation of Groundwater Recharge by Using Tritium–Helium-3 Dating Technique was held in Vienna from 11–15 June 2012. Eighteen researchers from eleven countries, including observers, participated in the meeting.

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

Despite the great potential of this methodology, a wider use of noble gas isotopes in hydrology is constrained by the limited analytical capacity worldwide and by tedious means of sample collection. The Isotope Hydrology Laboratory (IHL) has put much effort into setting up a noble gas analytical system for groundwater samples, with an unprecedented throughput over the last years, and has provided training to all participants on reliable water sampling during the first RCM meeting. The first RCM provided an opportunity to test our analytical and sampling methodologies to encourage wider and easier use of this technique and the 2nd RCM meeting was a good opportunity to receive evaluations from participants about the overall performance of the noble gas facility.

Since the first RCM meeting held in November 2011, ten research teams carried out field sampling campaigns and collected more than 200 water samples for noble gas analysis. Most of the analysis had been completed well before the meeting, and all participants presented their case studies during the meeting. These case studies targeted specific research objectives including evaluation of: the usefulness of the $^{3}H/^{3}He$ isotope technique for estimating recharge rates of aquifers in different hydrogeological settings; the use of $^{3}H/^{3}He$ isotope age dating for understanding groundwater–surface water interactions and groundwater discharge as baseflow to rivers and other surface water bodies and; the performance of different sampling techniques to provide guidelines for optimal use of the $^{3}H/^{3}He$ technique. It also compared recharge and discharge estimates with conceptual models and validation of methodology used with existing hydrological data and simplified groundwater flow and transport models.

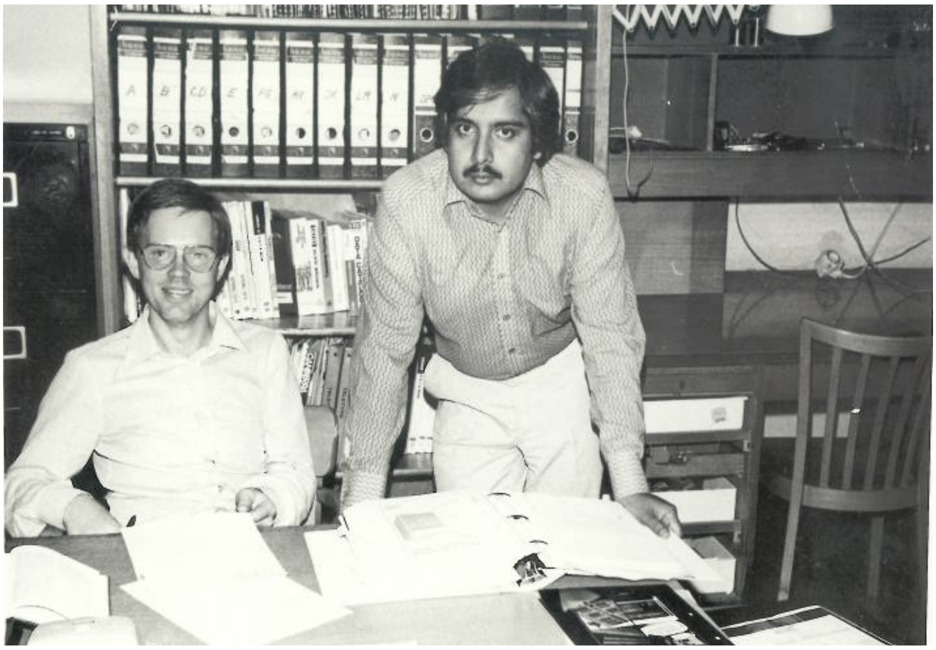
Participants discussed and evaluated the degree of success of each project. Research showed a clear correlation between groundwater ages and groundwater depths, which permits a reliable estimation of groundwater recharge rates. Some systems showed obvious signs of mixing of more than two different generations of groundwater in an aquifer, indicating the usefulness of the noble gas technique to precisely understand the origin and ages of complex groundwater systems.

The second round of the sampling campaign will start this summer and the IHL continues to improve its analytical capacity and methodology, based on several recommendations and requests provided by the participants of this meeting.

For further information, please contact Takuya Matsumoto at t.matsumoto@iaea.org

The Isotope Hydrology Laboratory: Then and Now

The Isotope Hydrology Laboratory has undergone major changes since its inception about 50 years ago, including the push brought about by technology. What is surprising is how much has stayed the same, from the goals of the laboratory to the dedication and inventiveness of its staff.



Wolfgang Wittmer (left) and Ahmad Tanweer in the late 1970s at the crowded initial location of the IH laboratory at Kärtnerring in the Grand Hotel (photo: IAEA).

Walking into the Isotope Hydrology Laboratory (IHL) of the IAEA today — a large, comfortable, well-lit, well-outfitted operation — it is difficult to imagine its humble beginnings.

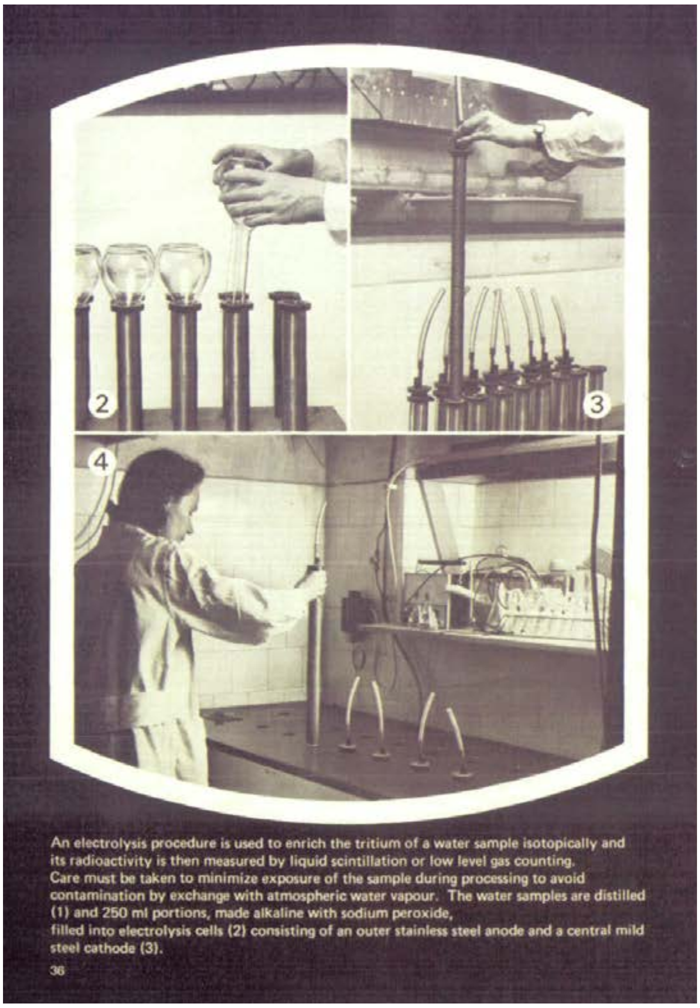
Today's lab — the only IAEA laboratory located at the UN headquarters in Vienna, because tritium contamination from the nuclear research reactor at the IAEA's Seibersdorf laboratory would upset isotope measurements — is based in minus 1 of the G Tower, and occupies around 890 m^2. That is 10 times more space than was available at its original location, a cramped 80 m^2 area in the basement of IAEA Headquarters on the Kärtnerring in Vienna in the Grand Hotel, where the Soviet army had headquartered between 1945 and 1955 before the Austrian government offered space to the IAEA in 1958. Approximately 50 years ago, the lab at Kärtnerring began generating its first results.

"We were really in the cellar, down, no windows, nothing," recalls Peter Schwarz, who worked at the IHL from 1963 until 1996 and observed the lab's development over that time. "It was the former kitchen, and only had ventilation holes from the bottom. Sometimes smoke came out of the lab and people called the fire brigade!"

The lab was meant to support the world's largest and most comprehensive collection of isotope data in atmospheric waters...

The IAEA's laboratory has strongly influenced the practice of isotope hydrology around the world. The lab was initially set up at the urging of the 1958 Advisory Committee, which thought it important that a laboratory be constructed for the isotopic analysis of samples, primarily tritium at that time. Tritium, or ^{3}H, occurs naturally in small amounts, but started to increase in the 1950s and reached its peak in the atmosphere and meteoric waters in 1963 in the Northern Hemisphere, as a consequence of large tritium releases during the testing of thermonuclear bombs, increasing the amount in the atmosphere by a factor of 1000 or more. Harmless to people in that amount, it made an excellent tracer for hydrological purposes. The Committee suggested that isotopes could provide information on water residence time in, and evaporation losses from, lakes and reservoirs, groundwater age and aquifer dynamics, continental water balance, age of hot spring water and mixing time of the oceans.

The lab was meant to support the world's largest and most comprehensive collection of isotope data in atmospheric waters, first called the IAEA/WMO (World Meteorological Organization) Isotopes in Precipitation network, now known as the Global Network of Isotopes in Precipitation (GNIP), which celebrated its 50th anniversary in 2010. Soon after



The 1973 IAEA Bulletin had a photo feature showing the steps taken by the IH lab to measure the very low levels of tritium in water.

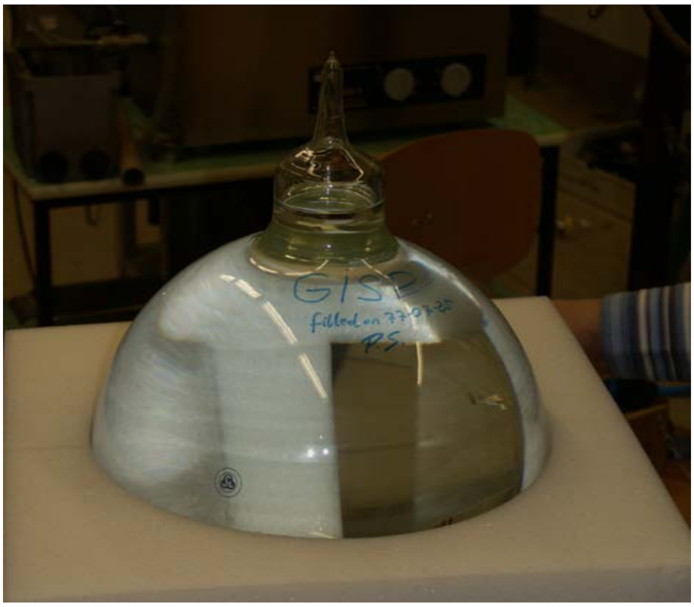
commencing the precipitation isotope monitoring project, it was realized that the IAEA must have its own laboratory to cope with the increasing number of samples and to standardize measurements from different laboratories contributing to the analysis of network samples. Isotope hydrology was still in its infancy, having been initiated at the beginning of the 1950s. Tritium and stable isotopes of water have been systematically used since the early 1960s for water resources inventory, planning and development, and this remains the main focus of the network today. The network has grown to include about 1000 current and historical stations around the world, producing over 120 000 monthly records.

In 1970, the lab was expanded to include analysis of hydrogen and oxygen stable isotopes, using a double inlet mass spectrometer. Prior to that, stable isotope measurements were processed at Willi Dansgaard's laboratory in Copenhagen. It is still a priority to assist Member States in conducting their own analysis of these isotopes.

The laboratory's role soon became internationally important, especially certain areas, such as that of worldwide intercomparison for tritium and stable isotopes, which is still undertaken approximately every four years to help labs maintain accurate results. In 2012, the latest worldwide test was undertaken for 137 laboratories conducting routine analysis of δ^2H and δ^{18}O in water by isotope-ratio mass spectrometry (IRMS) and laser absorption spectroscopy (LAS) (see p. 8). Such a test involves preparing a set of examples, distributing them to labs, and analyzing the results in order to provide feedback and uncover potential problems. The IH lab also quickly became a central exchange point for all major scientists in the field of isotope hydrology, "this was one purpose of the Agency", says Schwarz. There were big symposia, small working groups, visiting trainees, advisory groups and technical meetings. "It was about information exchange." The IH symposia are still held every four years and continue to draw scientists from around the world.

The IAEA helped make it easier to obtain high quality and inter-comparable measurements of stable isotopes and tritium from laboratories around the world. Before 1961, nearly every laboratory had its own reference for water isotopes and results were difficult to compare. For this reason, Harmon Craig introduced the concept of standard mean ocean water (SMOW) as a reference for stable oxygen and hydrogen isotope ratios of water. He

'Mr. A.E. Peckham of the Section of Hydrology determining the line of traverse for dropping bottles containing tritium-labelled water', IAEA Bulletin Vol. 19 No. 1 (1977). At the time, isotope hydrology was divided into two main branches: environmental isotope hydrology using naturally occurring isotopes, and artificial isotope hydrology, which made use of radioactive isotopes injected into the system under investigation. Artificial isotope hydrology has been used progressively less and less over the last decades. Despite the method at the time, nearly all samples were sent to the IH lab for testing; today many countries can test their own stable isotope samples.



A 10 L sealed glass bulb used for storage of reference material, in this case GISP (Greenland Ice Sheet Precipitation). The bulb was filled and flame sealed by Peter Schwarz in July 1977 (photo: IAEA).

defined SMOW with respect to an existing freshwater standard (NBS-18) which was a sample from the Potomac River in the United States in 1967 at the request of isotope geochemistry labs and with IAEA support. The virtual nature of SMOW presented some difficulties in calibration across many laboratories, and as a result, the IAEA asked Craig to prepare an actual sample of water with the isotopic composition of SMOW. V-SMOW, a physical standard based on Craig's SMOW was produced on a large scale for intercalibration purposes, and came into use in 1968. It was a composite of ocean water from various locations and depths, primarily from the Pacific, ideal because ocean water can be considered isotopically homogenous. South Pole ice (from the American Amundsen-Scott Base, 90°S) was used to create the isotopically very light SLAP (Standard Light Antarctic Precipitation) reference in the mid-70s to cover the range of water isotopes in nature.

"The Americans sent about 1000 kg of ice, packed with solid CO_2 to prevent melting," says Schwarz. When it arrived, the weight of the parcel was 500 kg less and everybody thought something had been stolen, but the CO_2 had simply evaporated, and the ice was still intact!"

Original facilities

The main initial equipment in the original lab included proportional gas counters for tritium and carbon-14; as already mentioned, the first mass spectrometer for stable isotopes was put into routine operation in 1970.

The first tritium gas counter was designed by Prof. Hans Oeschger from Bern University (after whom the Oeschger Centre for Climate Change Research is now named), says Schwarz. When it broke down at the beginning of 1964, he was requested to take it under his arm and go to Oeschger to find out how to fix it. "There were problems on the plane, of course, they thought it was a bomb!"

Later a second counter was used. The counters were placed inside other counters, used in addition to shielding. The outer counters correct for cosmic radiation, so-called anti-coincidence counting; a major concern for readings, because ambient radioactivity produces 1000 pulse counts per minute, and the laboratory wanted to measure tritium amounts as low as one count per minute. "Some put their counters in a piece of old cannon," says Schwarz. A 20 cm thick block of lead helped, but the real solution came when the lab moved to its current location in the Vienna International Centre in 1979.

Moving to headquarters

Plans were made to build a bunker deep in the basement, reinforced by materials from around the world, including ilmenite, a titanium-iron oxide mineral with high density and better shielding properties than concrete. The weight was so great and it was so close to a support pillar of the building that the pillar had to be reinforced to accommodate the bunker. "Not many of this type of bunker exist," says Schwarz. By the time the lab moved in 1979, the staff had grown from four to nine, and there were four gas counters, two enrichment facilities, two mass spectrometers, and the first gas preparation line for C-14.

The new lab was three years in the planning and it took nearly a year to move. A special firm for transport was required, having trucks outfitted with soft suspension so nothing would be broken. The gas counters were moved,

The MSP1 isotope ratio double inlet mass spectrometer was fully developed at the IAEA lab using some parts from older instruments. The machine was used for ^{18}O analysis of GNIP samples and TC projects for more than 10 years starting in 1987.

then the enrichment facility, then the mass spectrometers one by one, says Schwarz. The glass items had to be cut into smaller pieces for transport, then put back together.

The new lab was around 450 m^2, about half the size of what it is today, but still five times bigger than the first lab in Kärtnerring. When the Advisory Committee met in that significant meeting in 1958 which first established GNIP and promoted construction of a laboratory, it claimed "its optimal floor space would be in the order of 450m^2".

"The lab was expanded in 1998, and in 2005 we got more rooms", says Manfred Jaklitsch, who started in 1979 in the new lab, and still works there today.

> *'Everything was made by hand, even graphics. You cannot imagine how much work it was!'*
> — *Jaklitsch*

Equipment and supplies

In 1979, the machines were manually operated. Calculations were written in a book, and this was brought up to the isotope hydrology offices in a nearby, connected building of the Vienna International Centre. These results were later telexed or faxed to Member States, says Jaklitsch. "Everything was made by hand, even graphics," he says. "You cannot imagine how much work it was."

"Computers changed our lives completely," says Jaklitsch, "In 1987 we had our first IBM PC (which everyone used), then we had a lab database. Later we got a connection to the mainframe and copied our information every day to the main frame. No book was needed anymore. By the 1990s everyone had personal computers." The lab had one of the first LAN wireless connections around, in the early 1990s, says Jaklitsch. It was used to transfer data from instruments to the database.

The techniques used in mass spectrometry have also changed significantly over the years Jaklitsch has worked at the lab, but all those pale in comparison to the introduction of laser absorption spectroscopy (LAS) about five years ago. The relatively portable machines are inexpensive, easy to operate, and provide quick results. The lab has been conducting training courses since 2008 with about 60 people trained so far, and 30-35 machines have been supplied to Member States, with the demand for both growing. The development of LAS technology means that many countries can now measure their own stable isotopes in water, and do not have to send samples to the IH lab, rendering the mass spectrometer nearly obsolete. In earlier times, when providing isotope results to Member States was a priority, the IH lab measured 4000–5000 stable isotope samples per year and 1500 for tritium, according to Jaklitsch.

Modern developments

With the increasing ability of Member States to analyse stable isotopes on their own, the IH lab has shifted its focus to the analysis of radioisotopes for Member States — including tritium–helium-3 and noble gas isotopes — for groundwater dating. These isotopes, present in dissolved gases in groundwater, provide valuable information about climatic conditions during recharge, as well as the residence time of water at different time scales and its renewal rate.

Isotope Hydrology Section Head Pradeep Aggarwal (middle) explains to Deputy Director General Mohamad Daud the IHL's noble gas mass spectrometer and gas handling system (photo: IAEA).

As bomb tritium is now essentially washed out of the atmosphere, it is becoming more difficult to use, particularly in areas where travel time in the vadose zone may be more than 20–30 years, because of the need to use more sensitive and precise measurement techniques. Combined use of tritium and its decay product, helium-3 (^3He) is more useful. Despite the fact that hydrologic applications of ^3He have been recognized for over 30 years, scarce laboratory facilities have limited its use. The IAEA's helium isotope laboratory is already providing results to overcome this limitation and help build a comprehensive database of shallow groundwater ages from around the world.

Today, the IH lab is fully outfitted with the

Portable membrane contactor sampler for noble gas recently being put to the test in the field (photo: IAEA).

equipment required to measure with high precision noble gas concentrations and stable isotopes of noble gases from groundwater samples (such as ^{3}He, ^{4}He, ^{20}Ne, ^{22}Ne), as well as a chlorofluorocarbon (CFC) laboratory.

One thing hasn't changed; the inventiveness and innovativeness of the IH lab staff. The staff has built many

Gas extraction sampler for measurement of krypton isotopes. The IHL created this gas sampler based on the design of Neil Sturcchio from the University of Illinois, Chicago, It can extract and concentrate gases from a continuous flow of water in the field through a polyethylene membrane contactor. Prior to this, large amounts of water had to be transported to a laboratory to be measured (photo: IAEA).

of the machines in the lab, and is always finding creative ways to meet evolving activities and needs.

News in Brief

Arriving staff members

- In late May 2012, Darren Hillegonds joined the Isotope Hydrology Laboratory as a helium isotope mass spectrometry specialist. Following graduate school in analytical chemistry at Purdue University, Hillegonds spent 10 years at the United States Department of Energy's Lawrence Livermore National Laboratory (LLNL). As a career scientist at LLNL, he managed the noble gas mass spectrometry facility (a near match to the IHL instrument) while pursuing research on groundwater age dating, isotopic forensics for groundwater contaminants, and analytical development of new mass spectrometers. Hillegonds has also pursued isotope tracing in clinical research, primarily relating to development of a novel tracer for bone turnover rate in humans, utilizing accelerator mass spectrometry. He has also published in a diverse range of radiochemistry studies, including theoretical physics, cosmochemistry, radiocarbon dating, and therapeutic radioisotopes.

- Gustav Kainz joined the Isotope Hydrology Laboratory as a laboratory technician in December 2011. He is responsible for the electronic and electromechanical devices in the lab, including construction, modification repair, preventive maintenance and solutions After graduating from the HTL Wien1), he worked for different companies, where he did hard and software development and gained experience in different technological areas. He also has practical knowledge of high-voltage technology, high-vacuum technology, cryogenics, nuclear and X ray technology. Since starting at the lab, he has undertaken repairs/modifications on the mass spectrometers and noble gas extraction line, and is currently producing portable noble gas sampler units.

- Former consultants Bhishm Kumar and Dagnachew Belachew have joined the staff roster, Kumar in April 2012 and Belachew joined the staff in August 2012.

Departing staff members

- Tuerker Kurttas left the Isotope Hydrology Section in June 2012 after seven years of service. He was involved in the planning, managing and implementation of projects aimed at water resources management practices, techniques and technologies. He prepared materials for publication in relevant scientific publications, and was part of the team which prepared the Isotope Hydrology Atlases, specifically working on the Africa, America and Asia and Pacific atlases. The team was granted an award in 2010 in relation to the atlases. He was also part of the team involved in testing and running the recently developed liquid water stable isotope analyser, including preparing samples, measuring protocol and evaluating software. The same team, which Kurttas was part of, held regular training courses since 2008 and prepared training materials and software on the installation, running and maintaining of the laser machines. Kurttas also worked on a DVD on the use of isotope hydrology laboratory equipment. As a scientific secretary, Kurttas was responsible for planning, coordinating and implementing Coordinated Research Projects, as well as assisting in planning and implementing programmes in the field of water resources management practices, conducting analytical studies, participating in task forces, and providing technical input into the policy and standards development of regional and international bodies.

- Yakup Cevik worked in the Isotope Hydrology Section between 2008 and 2012 as a consultant. Cevik helped in the creation of the Isotope Hydrology atlases of Latin America and Morocco, compiling information for the creation of statistical book on isotopes in rivers. He was also involved in the development of elearning materials and map making.

Meetings

- The Isotope Hydrology Section presented information and had an outreach booth at the European Geosciences Union General Assembly 2012, held in Vienna. In total, 11 275 scientists from 95 countries participated, of which 28% were students.

- Members of the Isotope Hydrology Section held a session to introduce a graphical method for studying the changes in carbon isotope composition and dissolved organic carbon (DIC) concentration that can occur in reacting natural water systems. If the ^{14}C age of DIC were a simple function of radioactive decay of ^{14}C, the age of DIC in groundwater could be calculated from the measured amount of ^{14}C. However, estimation of the initial content, $^{14}C_0$, is not straightforward, and often physical and chemical processes, in addition to radioactive decay, alter $^{14}C_0$ in aquifers, so the determination of groundwater ^{14}C age is, in most cases, not that simple.

- IH staff presented a graphical method system allowing for qualitative inspection of measured data to recognize a number of effects that can modify ^{14}C composition in water, and, in combination with results obtained using more advanced dating models — such as geochemical adjustment models found using NETPATH — provide a better understanding of the systems under investigation and their radiocarbon ages.

- IH staff also presented information on the development of a portable membrane contactor sampler for noble gas analyses of surface and groundwater samples (photo above). The section has developed and tested a portable gas extraction device for noble gas extraction from ground and surface water as an alternative to conventional sampling methods. In order for all noble gases to reach equilibrium, the device requires ~45–60 min of continuous extraction at a water flow rate of ~3 L/min. Both laboratory and field tests of the sampling device yielded noble gas and isotope concentrations indistinguishable from those determined with the conventional copper tube method, indicating that the device can be used for groundwater sampling in a realistic field setting. The small size, portability, and equilibration time of about one hour are significant improvements over the conventional copper tube and diffusion samplers, and should facilitate a wider use of noble gas isotopes for hydrological investigations.

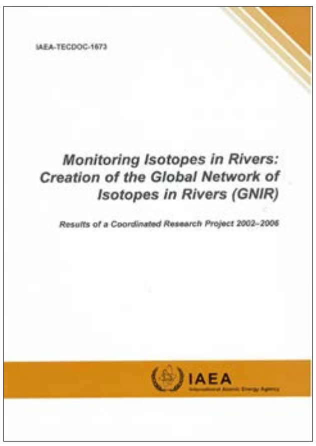
- The 6th World Water Forum (WWF) was held from 12 to 17 March 2012 at the Parc Chanot Exposition Center in Marseille, France and was organized by the World Water Council and the French Government. The theme of the meeting was “It is time for solutions and commitments!”

- The IAEA participated in order to bring forward its involvement in water and soil management to interested water stakeholders and to foster an understanding of the contribution of science and technology, particularly nuclear and isotope techniques for water studies and assessments and as well as available capacity building and technical support. The IAEA was represented by a total of 11 staff members from different departments and sections under the supervision of Daud Mohamad, Deputy Director General of Department of Nuclear Sciences and Applications. Its activities in this event were organized jointly by the Water Resources Programme (Isotope Hydrology Section), IAEA Environment Laboratories, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Department of Nuclear Energy and Department of Technical Cooperation.

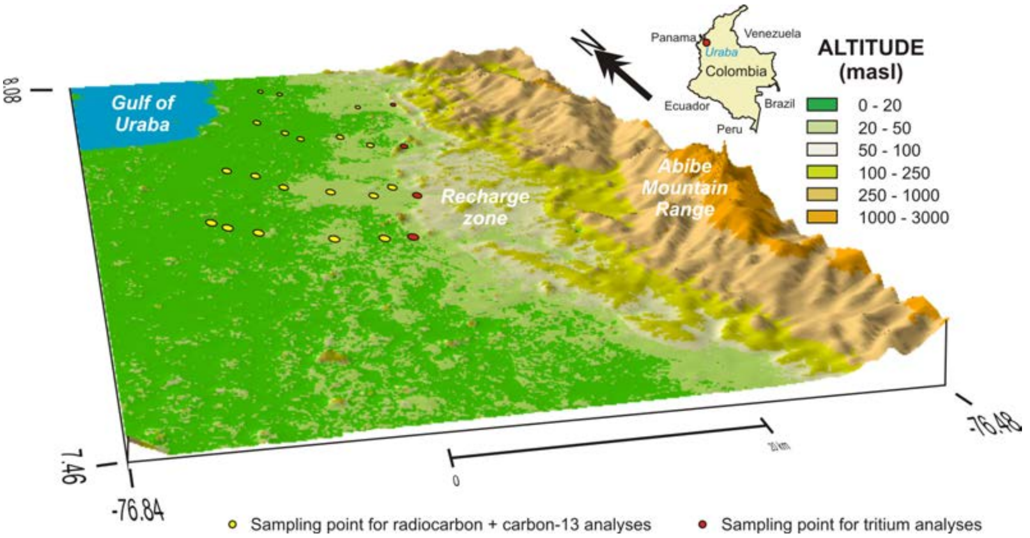
- The IAEA booth was organised in a way intended to highlight IAEA activities in different water resources applications and disciplines. Folders, handouts and promotional materials were distributed, and PowerPoint presentations and videos highlighting IAEA activities were shown throughout the week.

GNIR IAEA tecdoc released

River runoff plays a key role in human development in all societies through the provision of water for agriculture, industry and domestic use. Although the monitoring of water availability and our understanding of the main hydrological processes at the catchment scale are relatively good, many important aspects, especially those related to the interaction of runoff and groundwater, remain poorly understood. This publication presents several isotope datasets compiled for major rivers covering all continents, as well as preliminary conclusions.



Groundwater Flow in the Urabá Confined Aquifer Characterized Using Isotope Techniques



Study area in the Uraba region (Colombia). Confined aquifer groundwater flows, estimated from piezometric levels, go from East to West.

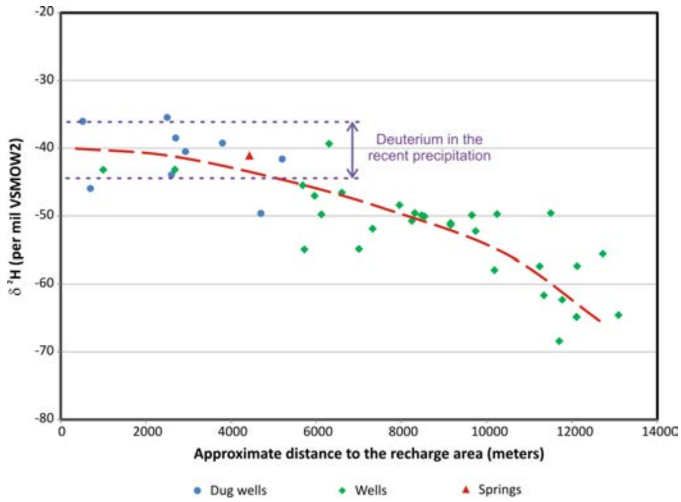
The IAEA currently provides assistance to Columbian counterparts in order to complete two isotope hydrology projects in Colombia. Stable isotope data has already been gathered, and carbon-14 data are now being analysed to complement and complete this investigation.

The project is being carried out in the northwest region at Urabá, Antioquia Department (figure above). The Urabá region is characterized by intense banana production, which exerts a high demand on the water resources. In addition, there are around 30 villages with a combined population of about 350 000 inhabitants. The objective of the hydrological study is to characterize the groundwater dynamics of a confined aquifer consisting of sandstones of continental origin that lie below geologically recent sediments. This geologic formation is slightly sloped to the west and crops out to the east in the foothills of the Abibe mountain range. This outcrop is expressed as a narrow strip striking north to south between 50 and 100 meters above sea level (recharge zone) (see above figure).

The environmental authority responsible for the management and protection of this aquifer (Corporation for the sustainable development of the Urabá - CORPOURABA) has been studying this aquifer because it is the main source of water for households and agro-industry. Its hydraulic properties have been estimated through pumping tests and estimated groundwater velocities vary from between 0.005 to 0.122 m/day. These velocities indicate that mean residence time in the aquifer lies within a range of between 300 and 7000 years at a distance of 14 km (a typical distance from point of recharge to the coastline). However, the isotopic signature of the water in this aquifer (deuterium and oxygen-18) is significantly different from that of recent precipitation, especially for groundwater in the west of the study area, further from the recharge zone (figure below). This suggests the age of groundwater may be greater than estimated using traditional tools.

To investigate this apparent inconsistency, samples were collected along four transects, each one following a different groundwater flow line (above figure). Groundwater dating through the analysis of carbon-14 is in progress. It is expected that this radioisotope will provide more precise information about the dynamics of flow in this aquifer and clarify the interpretations based on other research tools. This information will aid in the development of improved groundwater flow models, with positive implications for management. In this way, CORPOURABA will have a sounder scientific basis to review and improve plans for exploitation and protection of this groundwater resource.

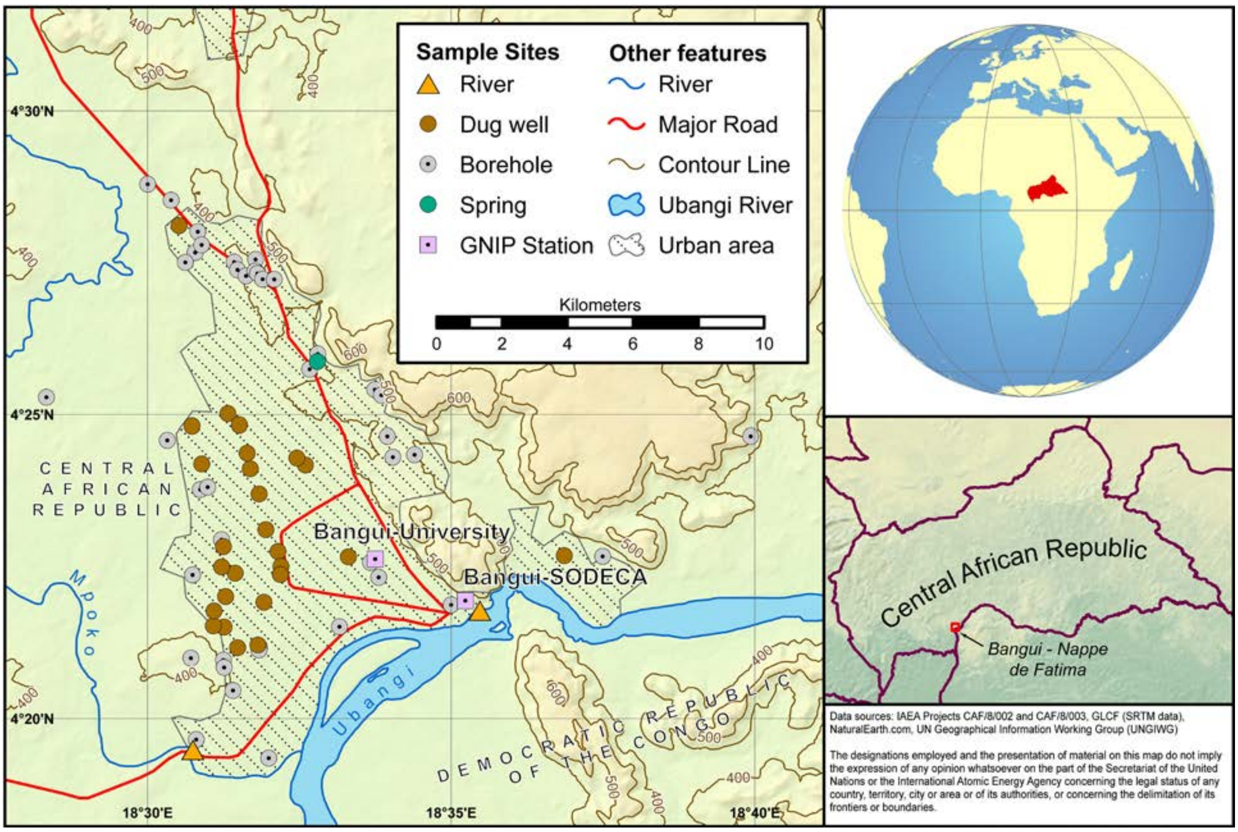
For further information, please contact Luis Toro-Espitia at l.toro-espitia@iaea.org).



Deuterium in groundwater, in relation to the distance to the recharge zone. The wells located in the west show more negative isotopic contents.

Central African Republic Uses Isotopes to Investigate Drinking Water Supply Potential

By E. Foto, C. Djebebe-Ndjiguim (Université de Bangui, Laboratoire Hydrosciences Lavoisier, Bangui, République Centrafricaine), F. Huneau (Université de Bordeaux, Talence, France), T. Vitvar (Czech Technical University in Prague, Czech Rep.), Y. Travi (Université d'Avignon, France), M. Ito (IAEA)



Map of the region studied.

The Central African Republic (about 623 000 km^2) is located slightly north of the equator in Central Africa (latitude 2^o – 11^{o}N; longitude 14^o – 28^{o}E); it has no coastal area (see map). Flat plateau savannas constitute a large part of the country, while hills are found in the northeast and the southwest; a granite plateau also exists in the northeast. The Ubangi and Shari river basins cover most of the country, and feature high flooding possibilities. The majority of the country has a tropical climate and desertification only exists in the northern regions. Bangui, the capital, is located in the Ubangi basin, the main tributary of the northern Congo basin. There are two seasons — a rainy season from May to October and a dry season November to March — with a maximum temperature in February–March of 33–34^{o}C (MET office). Although the Central African Republic receives a large quantity of precipitation annually (ca. 1500 mm per year) and has relatively abundant surface water, distribution is temporarily and geographically concentrated. Moreover, urbanization has led to densification of population in the capital and some other areas. Lacking adequate facilities to deal with these conditions, outflows of untreated sewage, agricultural runoff, effluents from mining areas as well as deforestation and soil erosion have degraded water quality. The majority of the population in Bangui does not have access to drinking water that is assured to be clean. Groundwater has been considered to be a great potential source of potable water in urban areas, but the quality and quantity of groundwater is not well known and its sustainable use is not certain.

Understanding aquifer systems

To meet the need for safe drinking water in the city, a technical cooperation project in isotope hydrology (CAF8002, 2007–2009) was initiated to investigate the hydrodynamics of the Fatima aquifer in Bangui. The subsequent TC project (CAF8003, 2009-2011) used isotope and hydrochemical techniques to better understand the aquifer systems under the city of Bangui for possible utilization of groundwater resources for safe drinking water.

Under the later TC project, 51 samples from surface water and groundwater (hand dug (HD) wells, less than 1 m deep; and boreholes (B)) were collected in September 2009 (the high water season) and 31 samples in April 2011 (the low water season). The sampling points were selected to cover the entire city of Bangui. Hydrochemical and physical parameter data suggest that HD type wells mainly consist of clays and silica compounds, while the B type wells reach the Precambrian carbonate formation. Two Global Network of Isotopes in Precipitation (GNIP) stations were established to collect monthly rainwater samples. One GNIP station is located on the University of Bangui campus in the central plain of Bangui (GNIP-University) and the other in the Sodeca gardens at a higher elevation on the western slope of the Pantheres hill (GNIP-Sodeca). The ^{2}H and ^{18}O values of rainwater at the GNIP-University station are more enriched than the values at the GNIP-Sodeca station. Surface water in the Ubangi River was also collected first bi-weekly and then monthly. The ^{2}H and ^{18}O values of the Ubangi River water are relatively depleted in the late wet season (maximum flow takes place in October) and enriched in the late dry season (low water occurs in April), corresponding to the pattern observed in the region's rainwater.

Dynamic recharge suggested

For groundwater, the ^{2}H and ^{18}O values of the majority of both HD and B groundwater types are found slightly above the Global Meteoric Water Line. However, there is a difference in the ^{2}H and ^{18}O values between these two types (see figure, right). The HD groundwater has a larger range of ^{2}H and ^{18}O values than the B groundwater, due to a greater variability in recharge conditions in shallow HD groundwater. In contrast, the stable isotope water values in B groundwater are less variable and fall between the rainwater values from the two GNIP stations. These results suggest that the deep aquifer is large enough to mix and homogenize local water with lateral inputs from hillside recharge water. The tritium values in groundwater, in both B and HD type wells, were between 0 and 5.4 TU. All HD and many B groundwater samples had tritium values similar to current rainwater values in the Central African region, suggesting dynamic recharge mechanisms via direct infiltration of recent rain in Bangui. The absence of or very low values of tritium (below the detection limit) in some samples from B type wells laid in Precambrian carbonates suggests that the water they produce is coming from a semi-confined aquifer with residence time of more than 50 years. Intermediate tritium values (2–3 TU) result from a mixture of surface water and groundwater.

The carbon-14 values in both B and HD well water (from 47 to 109 pMC) indicate that B groundwater is also modern, but as expected, the ^{14}C activity of shallow groundwater is closer to that of atmospheric activity. The residence time of samples with zero or very low tritium values was estimated using different models. Most of these B samples were modern, but two samples from the northern study sites were estimated to be in the order of hundreds or thousands years, based on the Fontes-Garnier model, the use of which is considered to be most appropriate. A conceptual model, integrating the results of isotope analyses as well as hydrochemical and physical parameter data, suggests complex aquifer system structures with several types of recharge mechanisms, including direct infiltration of rainfall to shallow levels, but with no clear lateral recharge from Ubangi river water.

Hydrochemical data suggest strong anthropogenic influences especially in shallow groundwater, including nitrate, sodium, chloride (which are from different sources) and potassium, among others, due in part to domestic waste water. Under a new TC project, the study continues to improve the understanding of aquifer systems for a safe drinking water supply, especially evaluating the apparently localized unpolluted and protected groundwater bodies in the upper Precambrian.

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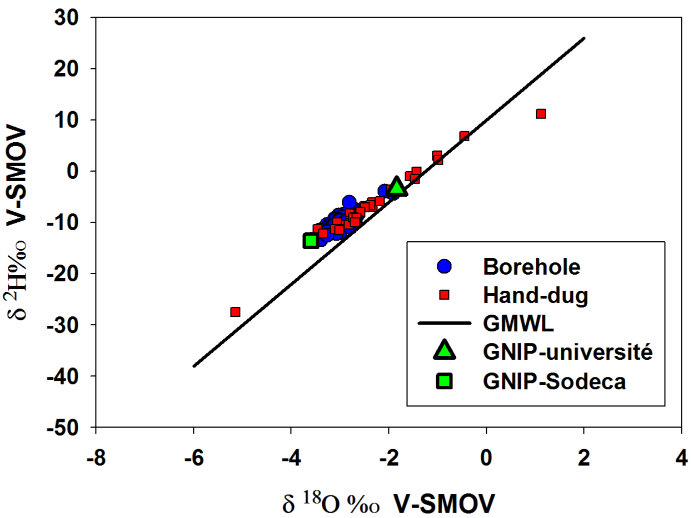
For further information , please contact Mari Ito (m.ito@iaea.org).



Graph depicting the large stable water isotope variability of dug wells vs boreholes in the study area.

Isotope Databases to be Overhauled

After a lengthy planning phase, January 2012 saw the starting signal of a renovation project for the Water Resources Programme's isotope databases. This undertaking involves not only the usual maintenance work, but includes an adaptation of all graphical user interfaces (particularly that of WISER, which serves as a 'window' to our data customers), an improved connection between in-house and externally-facing databases, and a general overhaul of the underlying data model. Apart from the IAEA's Water Resources Programme, the Business Solution Section of the IAEA IT Division, and the Cartography and Geoinformation Group, Department of Geography and Regional Research, University of Vienna, will participate in this project which is scheduled in two phases until late 2013.

A first important step included an evaluation of current system usability and user requirements. An on-line questionnaire was jointly developed by Mr Stefan Terzer, Isotope hydrology Section, and Mr David Schobesberger, usability specialist for mapping applications, University of Vienna. The WISER users were invited to rate strengths and weaknesses of the current system and to provide further input for application redesign. Around 600 (out of approximately 3000) WISER users responded to the call and provided their feedback. The outcomes form an integral part of the WISER redesign, but also gave the Water Resources Programme insight about its clients.

The participants of the survey were very diverse in terms of their country of residence. The highest number of participants came from the USA, followed by Germany and China. The distribution of participants positively reflects that the WISER system has a truly global outreach. It is very similar to the distribution of actual WISER site visits during 2011 as shown by Google Analytics (1. United States, 2. China, 3. Germany, 4. United Kingdom, 5. Spain, 6. France, 7. Japan, 8. Austria, 9. Canada, 10. Australia) (Google Inc., 2011). This congruence gives an indication that the most important user groups have all participated in the survey.

The largest group of participants worked in education (universities, colleges) (43%) followed by those employed by national or state government institutions (28%). At least 16% are students. The rest of participants can be separated in workers at commercial/private businesses (7%), non-profit-organizations (4%), employees of regional/local government institutions (3%), and international organizations (2%). Five per cent of participants could not be allocated to one of the above categories but were working in different organizations (e.g. national or public research institutes, consultants, retirement). Twenty-one participants indicatedthat they are concurrently staff/students at educational facilities. They could be lecturers,or doing project or PhD research.

By far the most important function and most frequently used is the data download, followed by the statistical treatments. Maps and diagrams are only used occasionally or rarely by most of the participants. This indicates that the data download and the related statistical treatments are by far the most important parts of the current system. These parts should also have priority in the redesign of the system and it is essential that they have high usability.

For further information or a PDF copy of the report, please contact Stefan Terzer (s.terzer@iaea.org).

Meetings in 2012

- HydroPREDICT'2012 Conference, Vienna, Austria, 24–27 September.
- Steering Committee meetings for GNIP and GNIR, Vienna, Austria, November/December.
- 1st RCM on the use of environmental isotopes to assess sustainability of intensively exploited aquifer systems, Vienna, Austria, 5–7 November.
- 1st RCM on environmental isotope and age dating methods to assess water quality issues in rivers affected by shallow groundwater discharges, Vienna, Austria, 05–07 December.

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