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In this Issue

IAEA General Director Yukiya Amano visits an isotope hydrology project in Ecuador in July (photo credit: ESPOL).

From the Section Head

The 13th quadrennial international symposium on isotope hydrology was hosted this year by the IAEA's Monaco Laboratory in recognition of its 50th anniversary (p. 2). The symposium, entitled Isotopes in Hydrology, Marine Ecosystems, and Climate Change Studies, attracted 280 participants over five days, from 28 March to 1 April. Sessions were held on the role of isotopes in understanding and modelling climate change, marine ecosystems and water cycles, carbon dioxide sequestration and related aspects of the carbon cycle, isotopes and radionuclides in the marine environment, groundwater assessments for large aquifers, and analytical methods and instrumentation. Participants included Member State representatives, scientists, technicians and organizations whose activities are relevant to the meeting subject matter. The IAEA intends to publish an edited proceedings of the symposium.

The Isotope Hydrology Laboratory (IHL) is turning its attention to noble gas isotopes dissolved in groundwater, which provide valuable information about climatic conditions during recharge, as well as the residence time of groundwater and its renewal rate. The isotope composition of noble gases can also serve as a geochemical fingerprint to decipher the origin of groundwater and flow patterns. The IHL has been successfully developing different gas sampling devices and testing them in the field. It is fully equipped with the equipment required to produce high quality isotope data from several types of noble gases in groundwater samples (p.5).

P. Aggarwal

IAEA Water Resources Programme

Quadrenniel Symposium Addresses Important Water and Climate Change Issues

By B. Newman (IAEA)

The International Symposium on Isotope Hydrology, Marine Ecosystems and Climate Change Studies examined five major topics through invited talks and oral presentations.

The International Symposium on Isotopes in Hydrology, Marine Ecosystems and Climate Change Studies, held in Monaco from 27 March-1 April, was formally opened by H.S.H Prince Albert II of Monaco seen in the photo above (photo credit: IAEA).

The International Symposium on Isotope Hydrology, Marine Ecosystems and Climate Change Studies was held from 27 March to 1 April 2011 in Monaco. This major IAEA meeting was jointly organized by the IAEA Water Resources Programme and the Marine and Environment Programme. The symposium was held at the Oceanographic Museum of Monaco to commemorate the 50th anniversary of the establishment of the IAEA Laboratory in the Principality of Monaco. The symposium also represented the thirteenth edition of the quadrennial symposium on isotope hydrology and water resources management, which has been regularly organized by the IAEA since 1963.

The symposium attracted 278 participants and observers from 67 Member States, covering aspects related to the use and application of isotope tools to address a broad spectrum of scientific disciplines through invited talks, oral and poster presentations and workshops. Developing countries were well represented with 120 participants attending. There were 49 oral presentations in the morning sessions and workshops, and 142 posters were shown. Brent Newman and Luis Araguas from the IAEA Water Resources Programme and Hartmut Nies from the IAEA Marine Environment Laboratory were the symposium's scientific secretaries.

Prince of Monaco

The Symposium was formally opened by H.S.H Prince Albert II of Monaco, followed by an invited talk on the interaction between climate science and climate change politics by Hartmut Grassl. Participants were able to enjoy the unique venue of the museum during the evening reception.

The Symposium addressed five major topics through invited talks and oral presentations during the morning sessions and poster sessions and dedicated workshops during the afternoon sessions. On Monday, the first topic addressed was the role of isotopes in understanding and modelling climate change. Oral and poster sessions explored a variety of climate related issues including paleoclimate reconstruction using groundwater and other proxies, and understanding impacts of anthopogenic activities using

various isotope approaches. The poster session also included a theme on isotope hydrology in which a large number of posters focused on the use of isotopes in understanding atmospheric moisture and precipitation, including isotope monitoring networks such as the IAEA Global Network of Isotopes in Precipitation (GNIP). Many isotope applications for surface water studies and water quality problems were also presented.

On Tuesday the symposium continued with a climate related theme, but was focused on the isotope related aspects of carbon sequestration and carbon cycling. Interesting talks were presented on the challenges of monitoring deep geological sequestration of carbon dioxide as well as carbon cycling in groundwater and the oceans. The themes of the afternoon poster session were analytical methods for isotope measurements and a second isotope hydrology session focused on isotope applications related to flow and transport modelling as well as general groundwater studies. The methods posters discussed new developments for measuring isotopes such as argon-39, as well as ways to improve isotope measurement accuracy.

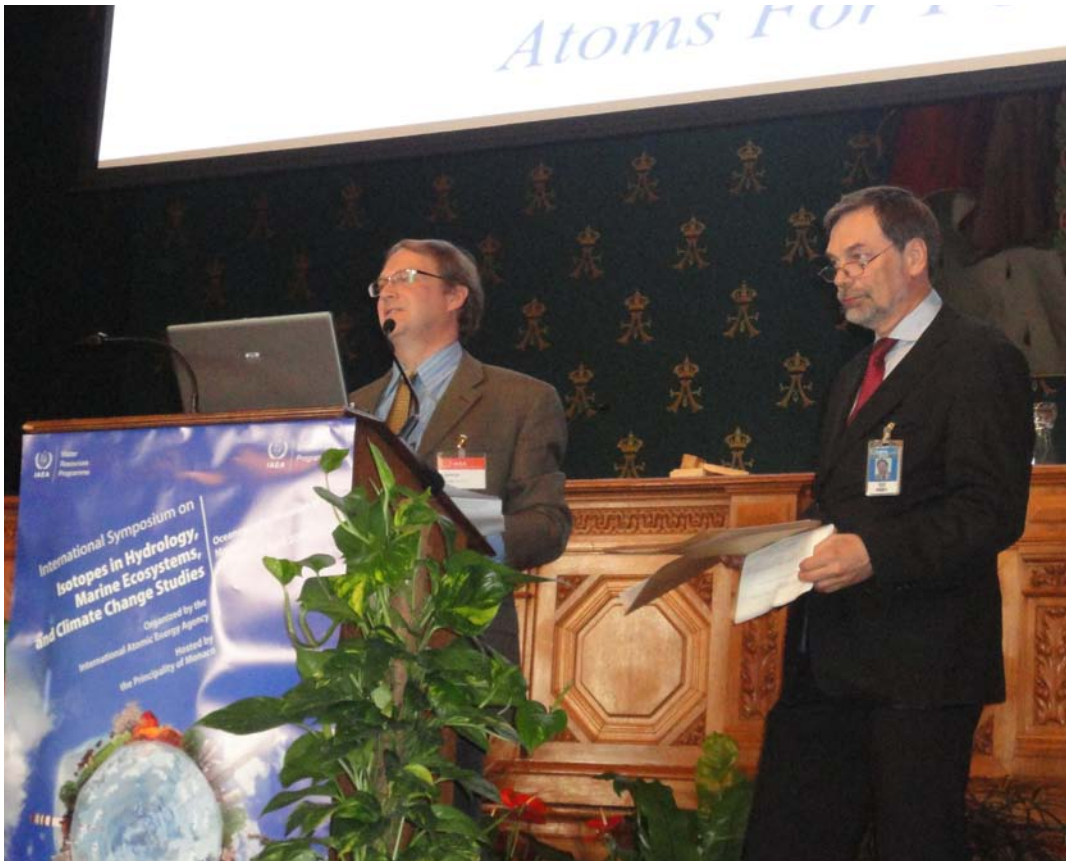
'The Symposium addressed five major topics through invited talks and oral presentations...'

Wednesday was dedicated to isotopes and radionuclides in the marine environment — a wide variety of marine related isotope techniques and applications were presented. Thursday was dedicated to hydrology and the morning session included a series of stimulating talks on groundwater assessments using satellite remote sensing and noble gases. Groundwater assessment case studies were also presented for Brazil, the Democratic Republic of Congo, Tunisia, and Turkey. The afternoon session was dedicated to a workshop on new frontiers and future directions in isotope hydrology. This session had a unique format; a series of experts led guided discussions with conference participants on four topics.

Extensive discussions

The first topic was on isotope monitoring networks and George Darling of the British Geological Survey led the discussion, which considered the value of isotope networks and issues regarding the expansion and maintenance of monitoring stations. Another important aspect of this topic was the increasing use and need for isotope mapping from basin to global scales. Issues and concerns related to the interpretation and use of isotope maps were discussed.

The second topic involved analytical developments and was led by Roland Purchert, of the University of Bern. Much of the initial discussion involved improvements in analytical methods for collecting and measuring noble gases. The topic finished with discussions on the emergence of laser absorption based stable isotope analysers.



Brent Newman, from the Isotope Hydrology section, takes the podium at the symposium, which attracted 278 participants and observers from 67 Member States. (Photo credit: IAEA).

The third topic was on hydrological residence times, with a discussion led by Jay Famiglietti of the University of California, Irvine. Issues about groundwater age/residence time terminology and interpretations were debated and the advantages of isotope tracers over conventional hydraulic measurements were described.

The fourth topic, on groundwater assessments, was led by Niel Sturchio from the University of Illinois in Chicago. The discussion started off with a talking point on what kind of information might be needed when starting an assessment of an aquifer about which little is known. This talking point led to discussions on which types of isotope samples one might first want to collect and what kinds of other geochemical or hydrologic information should be collected at the same time. From the discussion it was clear that properly planning an initial groundwater assessment is important to efficiently develop an understanding of a system and to decide what the best applications might be for future investigation.

'Presentations... illustrated the contributions of isotope tools in addressing many pressing issues in Member States...'

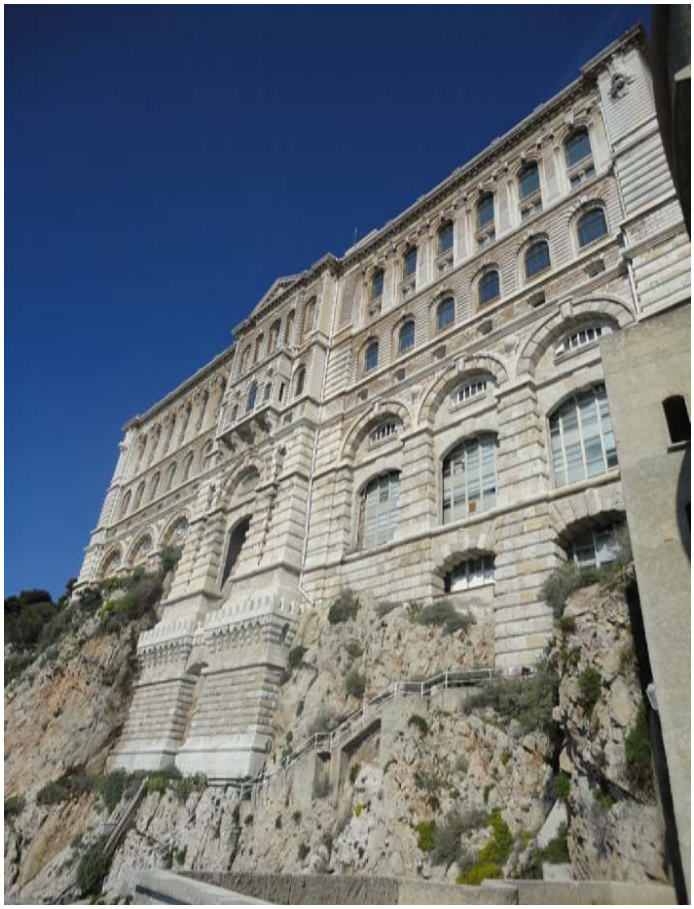
The symposium concluded on Friday morning with a series of talks on analytical methods and instrumentation. The session covered topics related to krypton-81 dating, novel cosmogenic radionuclides such as sodium-22, as well as other radionuclide methods. These talks were followed by a ceremony in which five young scientists (Vasileios Salamalkis, Fria Hadj Ammar, Wen Yu, Joachim Welte, and Helene Delattre) were presented with awards and bottles of champagne for their outstanding posters. The conference was then adjourned after closing comments by Pradeep Aggarwal and Maria Betti, director of the IAEA Environment Laboratories (NAEL).

In general, presentations by participants throughout the symposium illustrated the contributions of isotope tools in addressing many pressing issues in Member States regarding the need to conduct more sound assessments of water resources which will help meet sustainable management goals. In addition, it was clear that isotopes have a major role to play in understanding climate change issues and in the evaluation of mitigation strategies such as carbon sequestration.

Conclusion

The symposium constituted an excellent opportunity to review the current status and recent developments in the application of nuclear and isotope tools in the study of the water cycle, climate change, and marine systems. The special focus on assessments of water resources helped to maintain the idea that there needs to be a strong link between the application of isotope tools and water resource management and policy making decisions.

The symposium brought together experts and counterparts with a wide range of expertise compared to other similar meetings and this aspect was appreciated by many of the participants. The detailed symposium programme with links to PDF files of many of the oral presentations and posters are available by clicking on the symposium icon in the IAEA Water Resources Programme web page (www.IAEA.org/water). The IAEA is preparing to publish the edited proceedings of the symposium.



The symposium was held at a spectacular venue, the Oceanographic Museum of Monaco, to commemorate the 50th anniversary of the establishment of the IAEA Laboratory in the Principality of Monaco (Photo credit: IAEA).

For further information contact Brent Newman at B.Newman@iaea.org or Luis Araguas at L.Araguas@iaea.org

New Sampling Devices for Noble Gas Extraction from Groundwater

By T. Matsumoto, M. Jaklitsch and H. Liang-Feng (IHL, IAEA)

With the increasing ability of Member States to analyse stable isotopes on their own, the Isotope Hydrology Laboratory (IHL) is turning its focus to radioisotopes, including tritium–helium-3 and noble gas isotopes, for groundwater dating.

New methods developed by the Isotope Hydrology Laboratory (IHL) enable the time-efficient sampling of dissolved gas in water. Some of these methods were put into action (above) during a trip in June 2011 to the Fischa River in Austria (photo credit: IAEA).

Noble gas isotopes dissolved in groundwater provide valuable information about climatic conditions during recharge, as well as the residence time of groundwater and its renewal rate. The isotope composition of noble gases can also serve as a geochemical fingerprint to decipher the origin of groundwater and its flow patterns. The Isotope Hydrology Laboratory (IHL) of the IAEA is fully equipped with the 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}Ar, ^{22}Ar, etc.).

Conventionally, groundwater is sampled for He-3 using a copper tube, which is subsequently degassed using a vacuum extraction system for isotope analysis via mass spectrometer. Although this well-established way of sampling is widely recognised as reliable and robust, a major drawback to this method is its size and weight. A package of 24 samplers well exceeds 40 kg in a box measuring 120 × 30 × 30 cm. Considering that sampling sites are not necessarily easily accessible by vehicle, taking hundreds of samples in the field is generally a tough task for everyone. There is also a different type of sampler, comprised of a much smaller copper tube (6 mm in diameter and 10 cm long) with clamps and a semi-permeable membrane filter. It is sunk into water and left there for dissolved gases to diffuse into the sampler until their concentrations in water become equilibrated with those in the tube. This diffusion sampler is small and easy to handle in the field; it has an advantage over conventional copper tubes, as the diffusion sampler collects gases so that there is no gas extraction process needed before isotope analysis. However, this method requires an equilibration time of 24 hours or more, which could result in lower time-efficiency for sampling work.

The IHL has been developing a gas sampling device that enables the time-efficient sampling of dissolved gas in water in a smaller package that can be carried to the field like a suitcase (photo credit: IAEA).

More efficient device

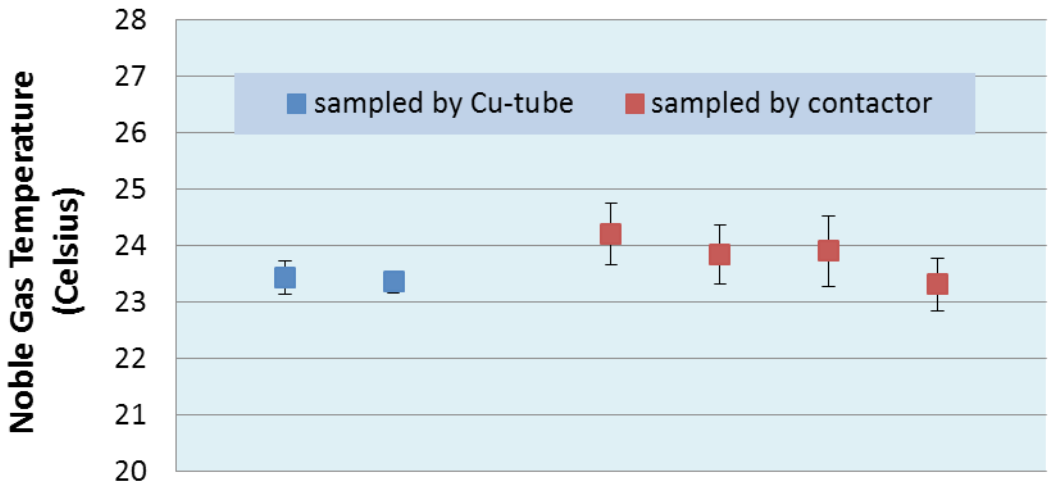
In our laboratory, we have been developing a gas sampling device that enables the time-efficient sampling of dissolved gas in water in a smaller package that can be carried to the field like a suitcase (see photo above). The device is based on membrane contactors previously published in scientific literature. The principle of the membrane contactor for He is the same as that used for Kr isotopes. It is designed to extract dissolved gas from a continuous flow of water by using polyethylene membrane contactors. Membrane contactors are fabricated with hydrophobic hollow-fiber microporous membranes with a pore size of 0.05 microns. At the pore, the gas phase will be in contact with the liquid phase, so that gases can be separated from water. A pump to create a vacuum in the gas side of the contactor and several sensors (for temperature and pressure) are packed into a durable plastic case with a rechargeable battery and a multi-channel data logger. The total weight of this sampler is about 10 kg, roughly the same as five conventional copper tubes.

'We have developed a gas sampling device that enables the time-efficient sampling of dissolved gas in water in a smaller package...'

Before accepting gases extracted from water flow, atmosphere in the contactor and sampler is evacuated using a vacuum pump. Next, water continuously flows through the membrane, a process which extracts gas molecules to the sampler volume. If the solution of gases in water is extracted under atmospheric pressure, the gas pressure of the sampler should approach atmospheric pressure at equilibrium. We have confirmed that equilibration can be achieved in a relatively short time and that it depends on the flow rates of water to the contactor (10 min for a flow rate of 6 L/min. and 20 minutes for 3 L/min.).

Noble gas determination comparison

We have recently carried out a comparison of noble gas determination with the IHL mass spectrometer on water



Noble gas temperatures calculated from the results of mass spectroscopic analysis agree with each other within respective analytical uncertainties.

prepared in the lab using a conventional copper tube and this contactor sampler. Samples taken from the same water bath using different methods showed consistent noble gas concentrations and isotopic ratios. This is demonstrated in the figure on p. 6, in which noble gas temperatures calculated from the results of mass spectroscopic analysis agree with each other within respective analytical uncertainties. The theory of noble gas temperature is that the solubility of noble gases is temperature dependent, and thus the temperature at which water equilibrates with the atmosphere can be calculated from noble gas concentrations. In the case of this experiment, both sampling methods show the room temperature of the laboratory. Based on this encouraging result, we are now testing a new sampling device in the field, in the hope that this method will soon be available to Member States as an effective and reliable sampling tool for dissolved gases in groundwater.

'This device can extract and concentrate gases from a continuous flow of water in the sampling field through the use of a polyethylene membrane contactor.'

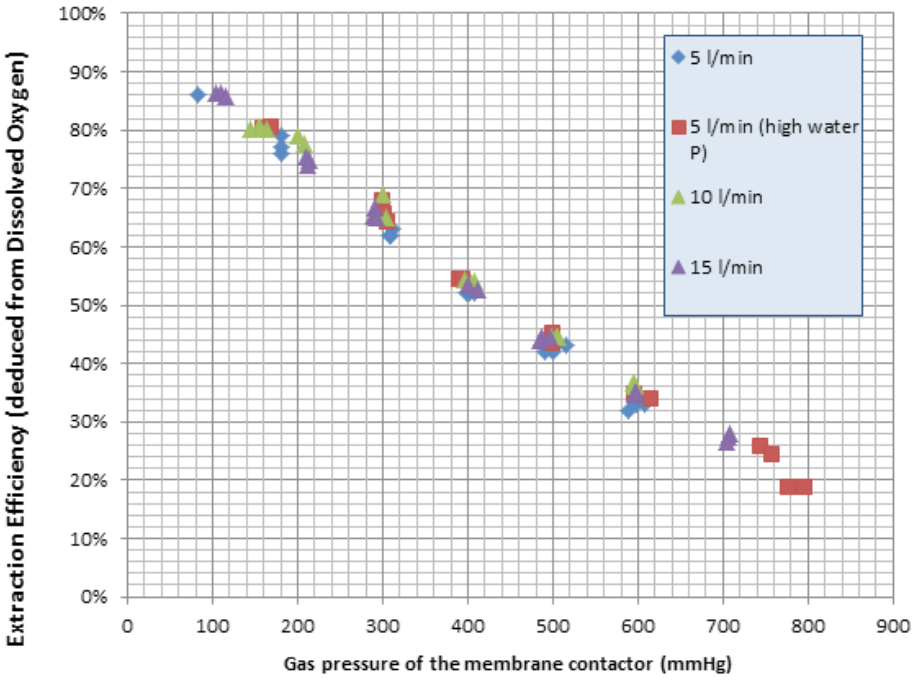
Krypton collection

The IHL has made a gas sampler based on the design of Mr Neil Sturchio from the University of Illinois, Chicago. Radioactive krypton isotopes (^{81}Kr and ^{85}Kr) have been proposed as reliable tools for groundwater dating. Krypton-81, the product of a cosmic ray induced reaction in the atmosphere, has a half-life of 229 000 years while ^{85}Kr, a fission product released during nuclear weapon testing and uranium/plutonium fuel reprocessing, has a half-life of 10.8 years. These isotopes are useful in the dating of both old (50 000–2 000 000 years with ^{81}Kr) and young (up to 100 year old with ^{85}Kr) groundwater. However, because their abundances are extremely low in nature, the amount of water required to obtain sufficient krypton isotopes is huge (>1 ton).

This device can extract and concentrate gases from a continuous flow of water in the sampling field through the use of a polyethylene membrane contactor. In order to determine the extraction efficiency of the device, we measured the dissolved oxygen (D.O.) of water into the device and out from the contactor by changing water flow rates, vacuum and water pressures.

The results are shown in the figure below, and it is clear that efficiency is not affected by flow rates of between 5 to 15 L/min and a water pressure of 1–2 atms, and that the contractor vacuum controls extraction efficiency; >80% of extraction is possible when gas pressure is maintained at around 200 mm Hg. Thus, this device can extract and concentrate quite efficiently (i.e. about 1 hour is needed to extract 1000 kg of water). A field test of this device will take place very soon and hopefully expand the capacity of the IHL in groundwater dating using radioactive krypton isotopes in the near future.

For further information contact Takuya Matsumoto at T.Matsumoto@iaea.org



Results of a gas sampler made by the IHL, which can extract and concentrate gases from a continuous flow of water in the sampling field through the use of a polyethylene membrane contactor. The results are similar to those obtained by Mr. Sturchio using his original design.

IWAVE Pilot Studies Reaching Milestones

By C. Dunning (IAEA)

The IWAVE Project, which intends to enhance the availability of fresh water through strengthening the capacity of Member States to conduct comprehensive assessments, has two pilot studies under way, with a third anticipated.

A water reservoir in the Philippines (photo credit: IAEA).

The IAEA Water Availability Enhancement Project (IWAVE Project) is directed to enabling Member States to enhance the availability of fresh water through comprehensive assessments of national water resources. A lack of adequate scientific data on water resources has been recognized for many decades; these problems persist as evidenced by the water issues that are part of the United Nations Millennium Development Goals (MDGs). IWAVE intends to enhance the availability of fresh water through strengthening the capacity of Member States to conduct comprehensive assessments. Fully realized comprehensive assessments will include water quality, water quantity and water use, as well as resource vulnerability and sustainability.

The IWAVE Project will focus on the fundamental hydrological data and information that are essential for conducting a comprehensive national water resource assessment. Gaps in hydrological data and information are particularly acute with respect to groundwater resources, which represent 97% of all freshwater resources. Groundwater holds great potential for many countries to address their national water crisis. Isotopic techniques count among the tools and approaches that could be used to improve the understanding of hydrological systems and assessments, thus they will be advocated when they are the best approach to solving a specific Member State hydrological gap.

The IWAVE Project has two pilot studies underway and a third is anticipated to start in 2011. The hydrological settings of these three pilot studies range from hyper-arid to tropical and will provide a thorough evaluation of the IWAVE Project approach. The milestones reached to date are listed below for each of the pilot studies.

Philippine Pilot Study

The first pilot study has been initiated in the Philippines in collaboration with the Philippine Nuclear Research Institute and the Philippine National Water Resources Board.

- A national workshop was held in Quezon City, Philippines in March 2011, convened by the Philippine Nuclear Research Institute and the Philippine National Water Resources Board. The workshop brought together about 60 Philippine water scientists and managers to work with nine international experts representing the IAEA, the US Geological Survey, GHD Australia, the Kansas Geological Survey (USA),

the World Meteorological Organization, the German Federal Institute for Geoscience and Natural Resources, the International Association of Hydrogeologists, and the University of Tokyo. The primary objective of the workshop was the development of Detailed Gap Profiles for each identified hydrological gap. The Philippine Pilot Study Steering Committee accepted the output of the workshop, and directed the Pilot Study Technical Working Group to move forward with appropriate steps to use the workshop output in developing a plan to address these gaps.

- A report characterizing the priority gaps in Philippine hydrological data and information is in preparation; Philippine experts are writing the report with the support of the IAEA. This report will be a synthesis of the output of the national workshop presented in the context that is most useful for informing agency and ministry level authorities on the current capacity of the Philippines to conduct comprehensive water resources assessments and the specific actions that are recommended to strengthen capacity to address priority gaps in hydrological data and information.
- Training, consultancy, and potential field sampling campaigns are planned for 2011.

Sultanate of Oman Pilot Study

The second pilot study has been initiated in the Sultanate of Oman in collaboration with the Peaceful Nuclear Technology Office of the Ministry of Foreign Affairs and the Ministry of Regional Municipalities and Water Resources.

- A preliminary mission was held in Muscat, Oman in March 2011 convened by the Ministry of Regional Municipalities and Water Resources. The workshop brought together more than 50 participants from the government, academia, and related institutions to learn about the IWAVE Project and begin discussion about gaps in hydrological data and information in Oman.
- A follow-up workshop meeting was held in May in Vienna with four participants from the Ministry and Petroleum Development Oman. This workshop defined in detail the priority gaps in knowledge and capacity in the area of groundwater assessment and management.
- An implementation plan was drafted at the follow-up workshop; the plan is to be discussed and approved by the Ministry for presentation at a national workshop. Some implementation activities are expected to be undertaken in 2011.
- A national workshop will be held in Muscat in late 2011 or early 2012, at which national and international experts will review in detail data and capacity gaps and the best means to fill them. Specific capacity building activities will be presented as a detailed work plan to fill hydrological gaps.

Costa Rica Pilot Study

The third pilot study is anticipated to be in Costa Rica; it will begin following a preliminary mission by the IAEA to San Jose at the invitation of the Embassy and Permanent Mission of Costa Rica in Vienna.

- A Preparatory Study on the hydrology of Costa Rica took place in preparation for a July 2011 IAEA preliminary mission.
- The preliminary mission was held in San Jose, Costa Rica; there the IWAVE Project was presented to participants from the government, academia, and related institutions. Also, early discussions were held on the nature of gaps in hydrological data and information in Costa Rica. This preliminary mission marks the initiation of the Costa Rica pilot study.

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

Participants of a follow-up workshop meeting held in Vienna in May 2011 included dignitaries from the Ministry and Petroleum Development Oman (photo credit: IAEA).

Isotope Hydrology Projects in Ethiopia Provide Valuable Information and Training

By T. Kassa (IAEA)

Water Resources Programme involvement in Ethiopian projects since 1991 has been extensive. The information and training provided have equipped the country to better resolve its water resource issues.

An Ethiopian technician making a water point inventory in the field (photo credit: Sileshi Mamo, Geological Survey of Ethiopia).

Background

The International Atomic Energy Agency (IAEA) has been working with the Ethiopian government in the areas of agriculture, nutrition, nuclear medicine and isotope hydrology over the last four decades.

Eight national and four regional Technical Cooperation (TC) projects (listed below) on isotope hydrology have been carried out in collaboration with various Ethiopian institutions over the last two decades (1991–2011). The IAEA has also been analyzing the monthly isotopic composition of rainfall samples collected from a meteorological station in Addis Ababa since 1961.

Environmental isotopes (^{2}H, ^{3}H, ^{18}O, ^{13}C and ^{14}C) have been used as complementary tools in water resource assessment and management and in geothermal studies. These isotopes have been implemented mainly to trace recharge provenance, estimate recharge rates and investigate lake–groundwater interaction in the Ethiopian Rift Valley. Nitrogen-15 isotopes were also used to trace the source of nitrate pollution in Diredawa, which lies in Ethiopia's south-east.

In addition, since 2000 there have been African Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA) related activities on the use of nuclear techniques

	Project Title	*Project Code*	*Period*	*Implementing Institutions*
1	Isotope Investigations in Selected Geothermal Fields	ETH/8/002	1991–1993	GSE
2	Isotope Study of Geothermal Fluids in the Ethiopian Rift Valley	ETH/8/003	1993–1998	GSE
3	Isotope Hydrological and Geothermal Studies of the Rift Valley(Aluto-Langano and Tendaho areas)	ETH/8/004	1998-2000	GSE
4	Use of Isotopes in the Study of Lake Beseka	ETH/8/005	1997–1998	MoWR
5	Isotope Techniques for Water Resource Management (Akaki well field modeling and Awassa Lake Level rise study)	ETH/8/006	1999–2001	GSE, AAU,MoWR& AAWSSA
6	Groundwater and Geothermal Resource Exploration in the Ethiopian Rift Valley and Adjacent Areas (Afar+Mekelle+Diredawa+Raya Valley)	ETH/8/007	2002–2005	GSE, MoWR,& AAU
7	Environmental Isotopes for Groundwater Management in the Afar Region (Awash River basin)	ETH/8/008	2005–2008	GSE, MoWR,& AAU
8	Assessment of Groundwater Resources in Selected River Basins	ETH/8/010	2008–2011	GSE, MoWR,& AAU

*See text

	Project Title	*Project Code*	*Period*	*Implementing Institutions*
1	Hydrology of Moyale region aquifers (Southern Ethiopia)	RAF/8/022	1995–2000	GSE
2	Sustainable Development and Equitable Utilization of the Common Nile Basin Water Resources	RAF/8/037	2003–2008	MoWR
3	Adding the Groundwater Dimension in the Nile River Basin	RAF/8/042	2007–Active	MoWR
4	Introducing Isotope Hydrology for Exploration and Management of Geothermal Resources in the African Rift System	RAF/8/047	2009–Active	GSE

in the assessment of siltation and leakage in lakes and reservoirs. Regional projects RAF/8/045, RAF/8/028 and RAF/8/026 on the investigation of leakage in dams and reservoirs have been conducted in Ethiopia and other AFRA member countries. However, local capacity and experience in the use of isotopes for assessment of dam leakage and siltation are still in their infancy.

Ethiopian counterpart institutions

Ethiopian counterpart institutions which have been working with the IAEA on the application of nuclear techniques in water resources and geothermal studies are:

1. Geological Survey of Ethiopia (GSE)
2. Ministry of Water Resources (MoWR)
3. Addis Ababa University (AAU)
4. Addis Ababa Water Supply and Sewage Authority (AAWSSA)

The Ministry of Science and Technology (MoST) has been serving as the liaison office between the IAEA and counterpart institutions, thereby facilitating technical cooperation with the Agency.

Achievements

- A considerable number of professionals and laboratory technicians have received training in isotope hydrology abroad as part of the IAEA's TC projects. Several national workshops on isotope hydrology have been conducted in Ethiopia in which a large number of water professionals have participated. These training programmes have had a significant impact on the capacity of the country to undertake water resource assessment, development and management.
- A National Isotope Hydrology Laboratory (NIHL) consisting of an ion chromatograph system (IC), atomic absorption spectroscopy (AAS), liquid scintillation counting system (LSC) and isotope laser analyser has been established at Addis Ababa University with the financial support of the IAEA. The laboratory has now started providing isotope analysis services to various organizations.
- Several pieces of field equipment and scientific literature have been supplied by the IAEA (including pH, electrical conductivity and dissolved oxygen meters, GPSs, computers, software, books and publications).

These pieces of equipment and scientific literature are currently being used by GSE, AAU, and MoWR.

- The Ethiopian Groundwater Resources Assessment Program (EGRAP), which envisages an accelerated groundwater resource assessment of the entire country, was designed by GSE and MoWR with technical and financial support of the IAEA and the USGS.
- An Ethiopian National Groundwater Database (ENGDA), released in February 2005, was prepared by the USGS with financial support from the IAEA. Data from about 5000 water points distributed throughout the country have been entered into the database. The database has been upgraded (making it bug free, more functional and enhancing capacity) by Schlumberger Water Services.
- A large number of water samples have been collected and analyzed for isotopes (^{2}H, ^{3}H, ^{18}O, ^{13}C and ^{14}C) at the IAEA's Isotope Hydrology Laboratory in Vienna. Based on these, technical reports, theses, publications, and an atlas of isotope hydrology have been prepared by Ethiopian institutions, individual researchers and the IAEA.
- Isotopes have been used to explain the occurrence and movement of groundwater in a multilayered volcanic aquifer system in the Ethiopian rift valley and adjacent plateaus and the relationship among different waters. Mixing processes among pure end members (young cold groundwater, lakes and geothermal waters) could be explained using isotopes. In general, isotopes have helped to build conceptual models of groundwater circulation which can be used to develop and manage this resource.

The way forward

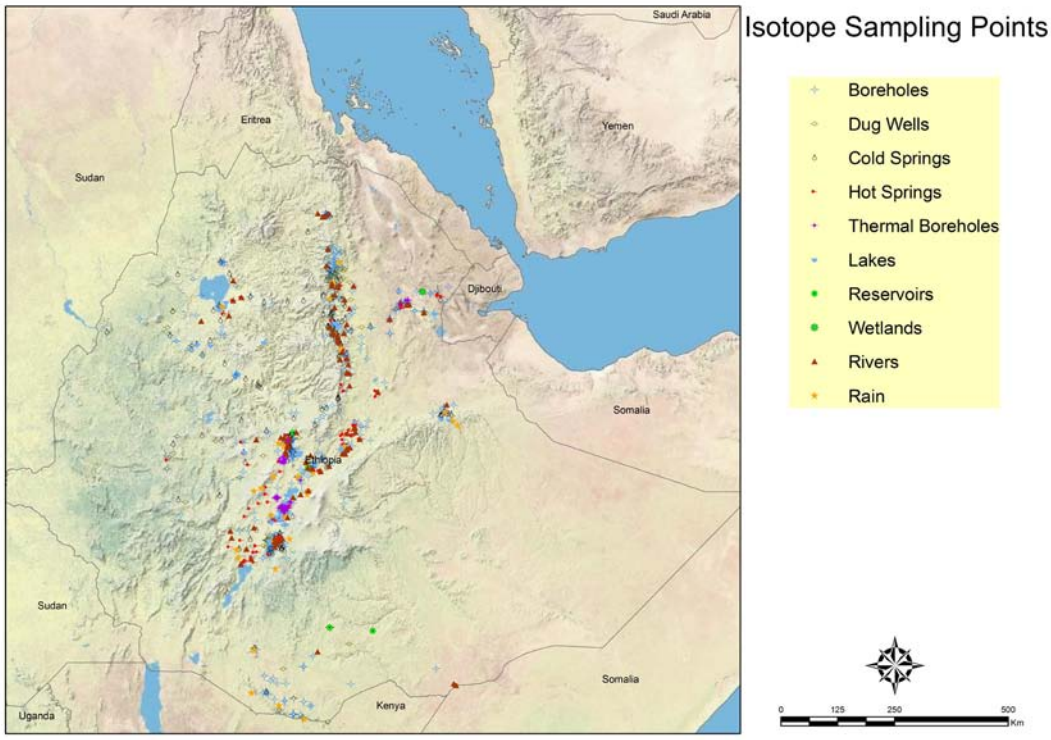
Areas which require further cooperation and intervention of major stakeholders are the establishment of more GNIP stations, the strengthening of the National Isotope Hydrology Laboratory at AAU, the establishment of groundwater monitoring networks, and data compilation, interpretation and reporting.

New GNIP stations

The IAEA has been analyzing isotopes in precipitation collected from the Addis Ababa station since 1961. However, due to diverse sources of air moisture, the Addis Ababa station does not represent the isotopic composition of rainfall country-wide. The nine GNIP stations (Gambela, Gore, Bahirdar, Mekelle, Semera, Awassa, Goba, Harar and Gode) proposed in 2005 would cover rainfall patterns, distribution and moisture sources for the entire country.

Although the IAEA has offered to support this effort, the lack of a responsible national institute to monitor new stations means this activity has not started yet. It is worthwhile to reconsider sampling using a new station. Since Ethiopia now has laser isotope spectroscopy and tritium analysis facilities, analytical work can be easily done inside the country. Major stakeholders, in particular AAU, GSE, MoWR and MoST, need to discuss and act on this issue again.

Equally important are the GNIR and MIBA programmes for river and moisture isotope monitoring, the details of which can be found on the Agency's website.



Map showing isotope sampling points corresponding to the many projects undertaken in Ethiopia over the last decades by the IAEA.

IH laboratory at Addis Ababa University

A National Isotope Hydrology Laboratory (NIHL) has been established at Addis Ababa University with the financial support of the IAEA.

Addis Ababa University was chosen to host the laboratory with the intention of supporting the postgraduate programme in hydrogeology. As a national center, the lab will also provide isotope analytical services to a broader range of users throughout the country. Provided it is well staffed, and equipped and managed on a sustainable basis, the centre could even serve as a regional center of excellence with regard to analytical services, training and research in isotope hydrology.

Water sample collection for isotope analysis from a flowing well sunk in basaltic aquifer in NW Ethiopia (photo credit: IAEA).

Groundwater monitoring network

Ethiopia is a large country with a diverse climatic, geological and hydrogeological environment. The effects of such natural complexity as well as those induced by humans, such as irrigation, pollution, and land use changes on groundwater resources, need to be monitored. There are wells which record for a short period, however there are no long term groundwater monitoring wells in Ethiopia.

'An impressive amount of chemical and isotopic data sets have been collected through TC and UNDP-1973 geothermal projects from the Ethiopian rift valley over the last 40 years.'

Considering the complexity of geology and rainfall regimes, about 50 monitoring wells equipped with appropriate devices would be adequate for the monitoring of groundwater in Ethiopia. Exact locations, numbers of wells, and parameters to be monitored could be decided after reviewing existing data and information.

Historical data

An impressive amount of chemical and isotopic data sets have been collected through TC, UNDP-1973 and other projects from the Ethiopian Rift Valley over the last 40 years. In the context of organizing, processing and interpreting all existing chemical, gas and isotope data for the Ethiopian Rift Valley, GSE has made some effort. However, the data have not yet been rigorously processed and interpreted. As a result, there are no simplified and regionalized conclusions drawn from these data.

Thorough interpretation of existing data would help in identification of data gaps and planning of future isotope hydrology projects. As an output of this activity, data will be compiled and interpreted and scientific reports will be produced.

Acknowledgement

Counterpart institutions are very grateful for the continuous technical support received by the IAEA. In particular, we would like to express our gratitude to the Department of Technical Cooperation and Isotope Hydrology Section of the IAEA for effective management of TC projects. The Ethiopian Ministry of Sciences and Technology has acted as a bridge between IAEA and local intuitions, thereby facilitating implementation of isotope hydrology projects in Ethiopia.

For further information contact Tessema Kassa at T.Kassa@iaea.org

EGU Session on Isotopes — Wetland Studies

Oral and poster sessions on Isotope Techniques for Understanding Wetlands and Agricultural Catchments was held on 5 April 2011 during the European Geosciences Union General Assembly 2011, which was held in Vienna 03–08 April 2011.

Participants of the Coordinated Research Project (CRP) on Isotopic Techniques for Assessment of Hydrological Processes in Wetlands decided to take the initiative in informing scientists, water resource managers and the general public of the usefulness of the application of isotope techniques in hydrological studies in the wetland environment during the Third Coordination Meeting held in September 2010. The EGU 2011 sessions presented such initiatives and was convened by several chief investigators and the Technical Officer of this CRP (Philippe Negrel of France as chief convener, Thomas Hein of Austria, Mari Ito of the IAEA-Isotope Hydrology Section, Randall Hunt from the United States of America, Marisol Manzano of Spain) as well as three other co-conveners who covered agricultural watersheds.

These sessions were among the largest held at the 2011 EGU General Assembly. The oral session included presentations from this CRP by: M. Sanda et al. of the Czech Republic (invited speaker), E. Bocanegra et al. of Argentina, M. Manzano et al. of Spain, and N. Welti et al. of Austria, among others. Some participants of this CRP also presented posters, including, for example, a study by P. Negrel et al. of France. A poster by M. Ito and P. Aggarwal of the IAEA Isotope Hydrology Section and 17 chief participants of this CRP (Argentina, Australia, Austria, Brazil, Cameroon, Colombia, the Czech Republic, France, Ghana, India, Mozambique, Pakistan, Spain, United Republic of Tanzania, Uganda, UK, USA) presented a CRP summary, outlining the role of isotope techniques in hydrological studies in wetlands together with case studies in Australia (S. Lamontagne, et al.), Austria (N. Welti, T. Hein, et al.), Cameroon (E. Hornibrook, A. S. Tesung, et al.), Spain (M. Manzano, et al.), and the USA (R. Hunt, et al.).

News in Brief

Departing Staff Members

• Mr. Paul Gremillion joined the Isotope Hydrology Section as a consultant in July 2009. During his two-year stay at the section he worked on regional projects in Africa, including the Nubian Sandstone Aquifer Project and the Nile River Basin Project, as well as helping with the IWAVE project.

Awards

• The Isotope Hydrology Section recently won awards in two categories: Best website or CD on training packages, databases, information networks on a specific theme in 2008–2009 for its Laser Spectroscopic Analysis of Liquid Water Samples for Stable Hydrogen and Oxygen Isotopes, and special award for outstanding publication in 2008–2009 for its Atlases of Isotope Hydrology. A total of three volumes were considered, including Africa (2007), Asia and the Pacific (2008), and the Americas (2009).

• Obituary

Giammaria Zuppi, born in Rome, passed away in Rome on 13 May 2011, at the age of 64. Between 1977–1981, he joined the Isotope Hydrology Section (IHS), where he collaborated in a number of TC projects in many countries. When he returned to Italy, he worked as professor of hydrogeology at the University of Turin until 1993, when he had a temporary appointment at the University of Paris Sud (Orsay) as Director of the Institute of Hydrology and Isotope Geochemistry, replacing Prof. Jean-Charles Fontes while he was in Vienna as head of the IHS. After Prof. Fontes died unexpectedly in 1994 during a field mission, Giammaria remained in Orsay until 1995 and then resumed his post in Turin. In 1996, he became Professor of Hydrogeology at the University Ca' Foscari in Venice. In 2008 he was appointed Director of the Institute of Environmental Geology and Geo-engineering (IGAG) in Rome, where he remained until his death.

Giammaria was scientifically very active, especially in the application of stable isotopes in water sciences, and produced several articles in international journals. With his hydrogeological and geochemical background, he had the ideal profile of an isotope hydrologist. He had many pupils and contributed to the formation of several young isotope hydrologists who later used isotope techniques in their professional life. All his (many) friends will miss him, his humour and merry mood, as well as his generosity and good nature.

Data Sets for Simultaneous Water Vapour and Rain Sampling Used in Modelling Efforts

By N. Kurita (IAEA)

The Isotope Hydrology Section has been testing a newly available automated precipitation sampler to obtain short term isotopic data on precipitation and a laser spectroscopy analyzer for water vapour isotope analysis.

Automated precipitation sampler at the IAEA Isotope Hydrology Laboratory. The sampler was designed and manufactured by T. Coplen (USGS) (photo credit: IAEA).

Introduction

The reliability of model based future climate scenarios described in the Intergovernmental Panel on Climate Change (IPCC) assessment report depends on how these models can simulate the observed present day climate – both globally and at the regional level. It is well known that the climate models fail to simulate the observed precipitation field in the tropics and there are wide variations between models for the simulated global field. Recently, to reduce these model uncertainties, a high resolution climate model was developed and a more realistic scheme incorporated into the model. These developments may contribute to improving the reproducibility of present day climate, though an accurate simulation of the present day climate field does not guarantee a precise future prediction. One of the most important things for future prediction is whether the current climate model can reproduce key climate processes both in the present and the past.

Powerful tools

Water isotopes HDO (deuterium) and $H_2{}^{18}O$, are very powerful tools that can be used for this purpose. Their variability in the atmosphere is related to the source of moisture and the integrated histories of both condensation and evaporation during travel from the source to the deposition site. Hence, good representation of observed global isotopic patterns and their seasonality indicate that models can reasonably simulate real atmospheric circulation and key climate processes. Although water isotope tracers are useful in the study of global climate change, until now their usage has been limited. One of the main reasons is that most available data is monthly mean precipitation isotopic data, thus isotope data for moisture sources and short term isotopic data are deficit.

In order to expand the use of water isotopes to include study of global climate change, the isotope hydrology section of the IAEA is testing a newly available automated precipitation sampler to obtain short term isotopic data of precipitation (see picture above) and a laser spectroscopy analyzer for water vapor isotope analysis for continuous water vapor isotope measurement in surface water vapor (see picture on the following page).

The main purpose of this programme is to establish measurement procedures to gain accurate isotope data

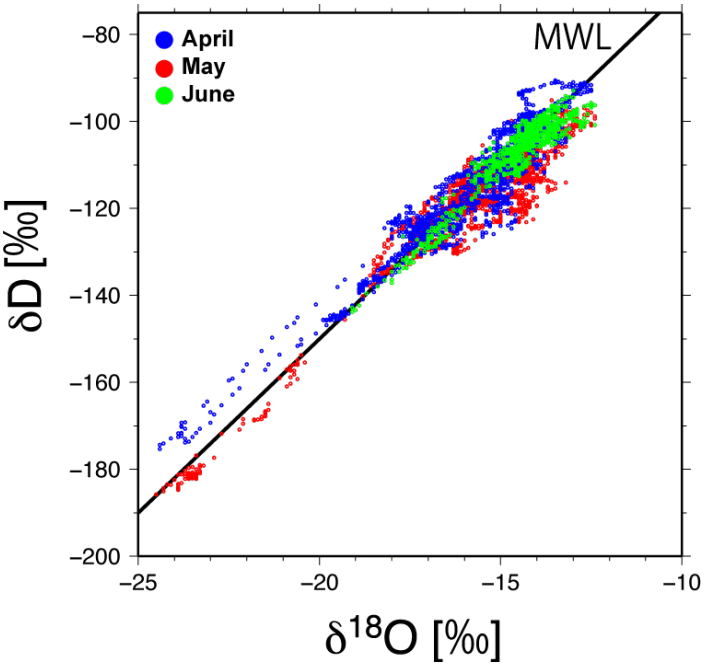
Laser spectroscopy analyzer for water vapour isotope analysis for continuous water vapour isotopes measurement in surface water vapour (photo credit: IAEA).

using these instruments. This activity, which was launched in May 2011, is still going on. The figures here introduce some preliminary results.

Continuous measurement

The δD–δ^{18}O plot in surface water vapour is shown in the upper right figure. As was done in previous studies, most data is plotted on the Meteoric Water Line (MWL).

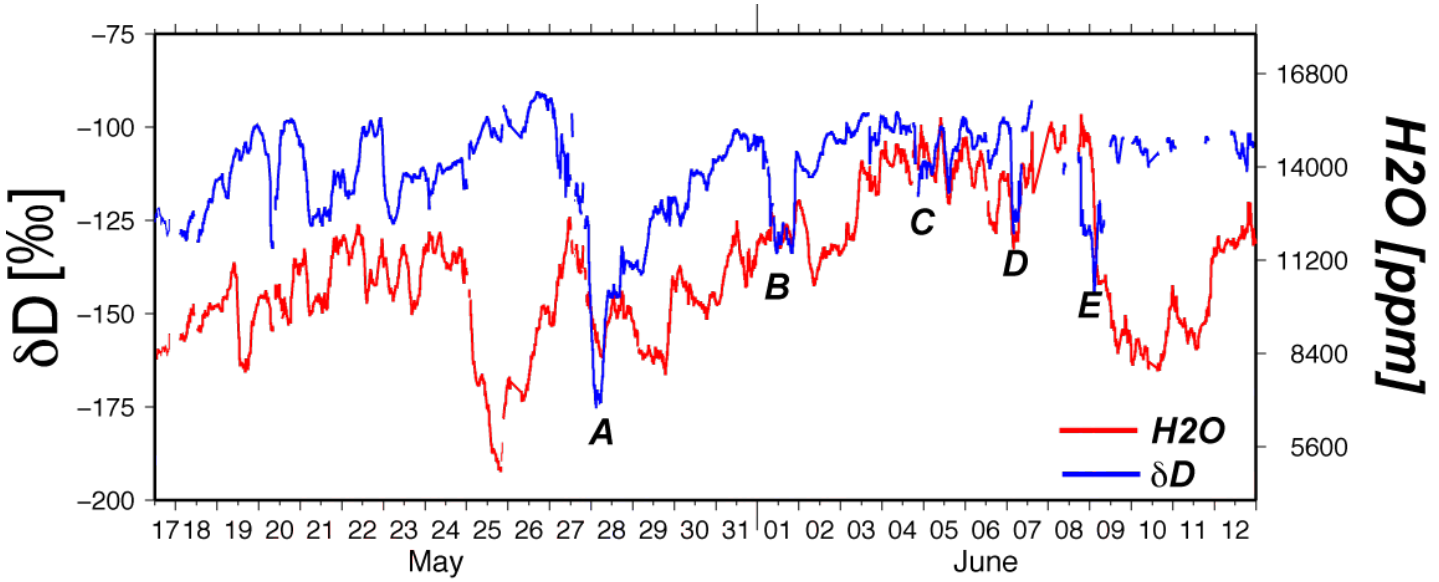
A time series of δD values in surface water vapour is shown below. Although it is well known that δD values of precipitation follow temperature and humidity changes, the evolution of δD values does not correspond to that of water vapour concentration. In addition, repeated, abrupt δD depletions occasionally appeared after a heavy rainfall



The δD-δ^{18}O plot for surface water vapour.

event (labeled A–E in figure below) and these lower isotopic signals are accompanied by a surface temperature drop. To explain, the enhanced downward moving moisture flux (downdraft/subsident) transports free tropospheric moisture with depleted δD values to the surface. Newly available short term isotopic variation data can provide a new hydrological perspective in understanding vertical moisture transport, thus the application of isotope tracers enables validation of the physical processes of the climate model.

For further information contact Naoyuki Kurita at N.Kurita@iaea.org



Time series with a 10 min average δD and water vapour content in surface water vapour in Vienna over the period of a month. The lowest peaks in δD values are associated with heavy rainfall events, and are labeled A–E.

Second Coordination Meeting Solidifies Goals

Participants at the second coordination meeting for a regional TC project on isotopes in Africa (photo credit: IAEA).

The second coordination meeting for a regional technical cooperation (TC) project on isotope hydrology in Africa, entitled Building Capacity in Support of Regional and Sub-Regional Water Resources Planning, Development and Management in Africa (RAF/8/048), was held in Rabat, Morocco from 24–27 May 2011. The project, which began in 2009, is aimed at building and strengthening capacity in the application of isotope techniques in water resources management, not only through providing training courses, which is a major component of the project, but also by encouraging and entrusting the leadership of selected institutions to lead the effort for capacity building in the application of isotope techniques in water resource studies and management and providing analytical services in the region (regional designated centres: RDCs) and national and sub-regional activities led by national governments. Three RDCs were selected in 2010, one each in Egypt, Morocco, and Tunisia.

The second coordination meeting for this project was hosted by the Moroccan National Centre for Nuclear Energy, Science and Technology (Centre National de l'Energie, des Sciences et des Techniques Nucleaires: CNESTEN). National project coordinators from Burkina Faso, Egypt, Ethiopia, Madagascar, Mali, Morocco (the representative of which was also the Project Scientific Consultant), Niger, Sudan, Tunisia and the United Republic of Tanzania participated in the meeting.

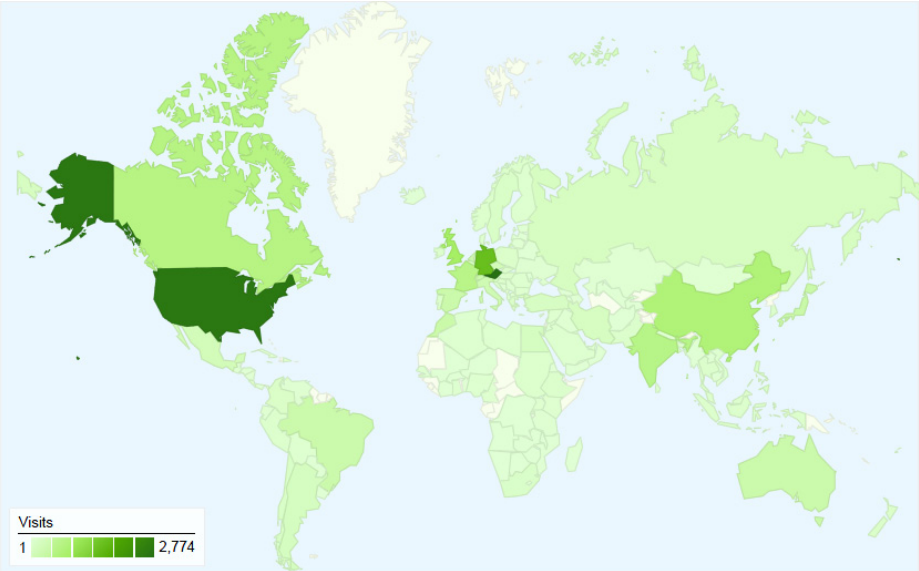
In the meeting, the participants reviewed and evaluated activities that have been conducted at the national level under RAF/8/048 as well as at the project level, including the training courses held in Addis Ababa, Ethiopia in 2009, in Rabat, Morocco in 2010 and the selection of the RDCs in 2010. The meeting also examined activities that had been previously planned, but not implemented during the past two years.

Module development

The participants agreed that the RDCs and a few selected countries would play a leading role, in consultation with the IAEA, in developing a university module on isotope hydrology for use in Africa, based on the existing university modules in Africa and available reading and audio-visual materials and resources. They then discussed and agreed upon activities to be conducted for the next 2.5 years, including training courses. The participants recognized the importance of compiling existing data and information for isotope hydrology and related water resource studies and the need for assessment of analytical capability at the national level. It was agreed that these activities would be conducted under this project.

A representative of the UNESCO regional office also participated in a part of the meeting and a small discussion extended to possible cooperation with the UNESCO regional office in the future, for capacity building in water resource studies and management in the region. CNESTEN invited meeting participants to visit the isotope hydrology laboratory and the nuclear research reactor at the Centre. The second coordination meeting reconfirmed that Africa's own initiative for capacity is important and that the RDCs will lead this effort with the cooperation of participating countries under the present project.

IH Web Site Drawing Many Users



Visitors to the Water Resources Programme Web Site.

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.

Statistics show that the Water Resources Programme web site has drawn 17 732 visits from 150 countries/territories for the year 2010 between 1 January and 31 December. The section released a new design in March 2010, and usage has risen significantly since that time, according to Google Analytics. The statistics show that monthly average visits were approximately 1773 per month, with 9734 absolute unique visitors (addresses counted only once) and 54 958 page views.

A breakdown by continent showed that Europeans used the website by far the most, representing 48.84% of total users, the Americas were second (25.49%), then came Asia (16.62%), Africa (6.60%), and Oceania (2.31%) (see graph above right). The top 10 visitors by country with the heaviest user first are: Austria, United States of America, Germany, United Kingdom, China, Canada, India, France, Japan, Morocco.

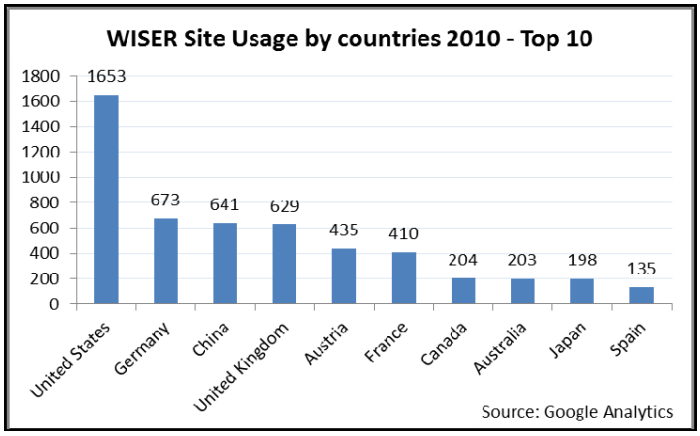
Statistics on use of the WISER (Water Isotope System for Data Analysis, Visualization and Electronic Retrieval) mapping tool for 2010 are shown in the bottom left graph.

Dynamic layout and structure

The section spent several months working on the creation of a new, dynamic layout and structure. Features of the new design include direct access to a collection of technical documents related to isotope hydrology as well as symposia, monographs, newsletters, fact sheets, brochures, videos, and learning tools. A project in which symposia and monograph documents on isotope hydrology and related fields from 1963 to the present day are being scanned and stored, will be a great tool for the isotope hydrology community, as well as preserving the heritage of the science. Many of these documents are out of print or otherwise unavailable. The web site project is part of an overall reworking of IAEA sites by individual sections, as well as a department wide web presence restructuring.

Currently, the Isotope Hydrology Laboratory (IHL) page for the web site is being updated, and all the latest information about laboratory services, as well as slide shows displaying equipment and field work, will soon be available.

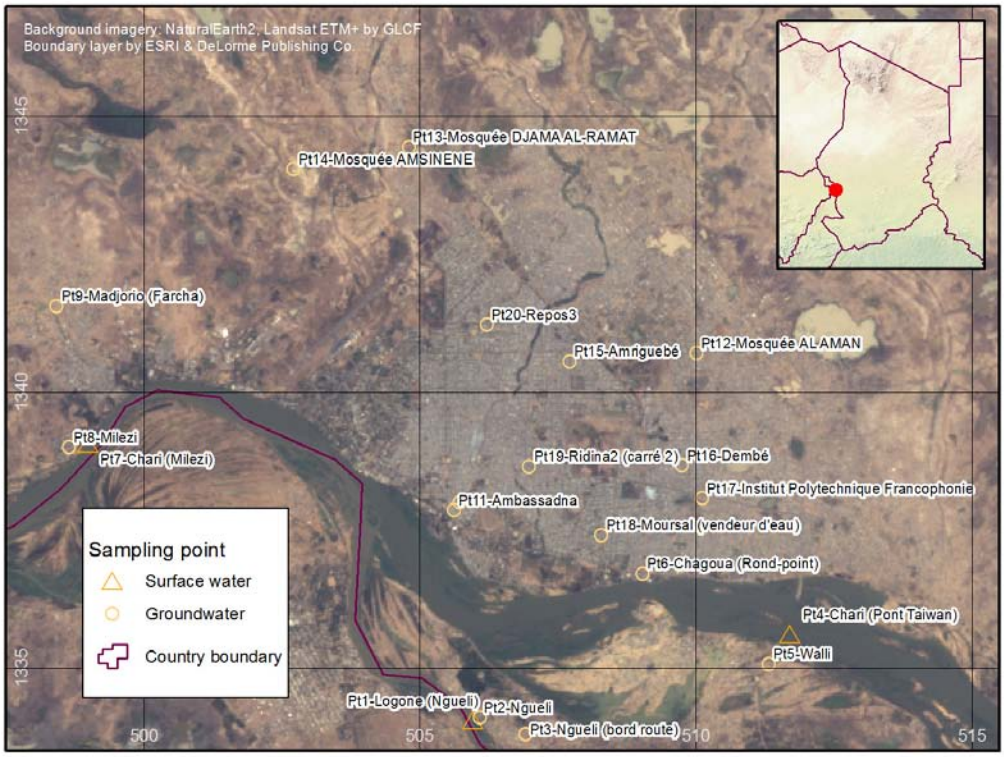
Country/Territory	Visits	
Austria	2,774	15.64%
United States	2,686	15.15%
Germany	1,579	8.90%
United Kingdom	903	5.09%
China	747	4.21%
Canada	658	3.71%
India	628	3.54%
France	619	3.49%
Japan	348	1.96%
Morocco	343	1.93%



Isotope Techniques Applied to Find Drinking Water Supply for Chadian City

By M. Ali Abdelkerim Annadif (Ministère de l'Eau; Direction de la Connaissance du Domaine Hydraulique; N'Djamena, Chad), Y. Travi (Université d'Avignon et des Pays du Vaucluse, France), F. Huneau (Université de Bordeaux, France), T. Vitvar (Czech Technical Univ., Prague, Czech Rep.), M. Ito (IAEA)

Chad is facing a water crunch with a growing population and shortage of fresh drinking water. High mortality is considered to be largely due to the undesirable drinking water supply situation and poor sanitary conditions.



Location of sampling points.

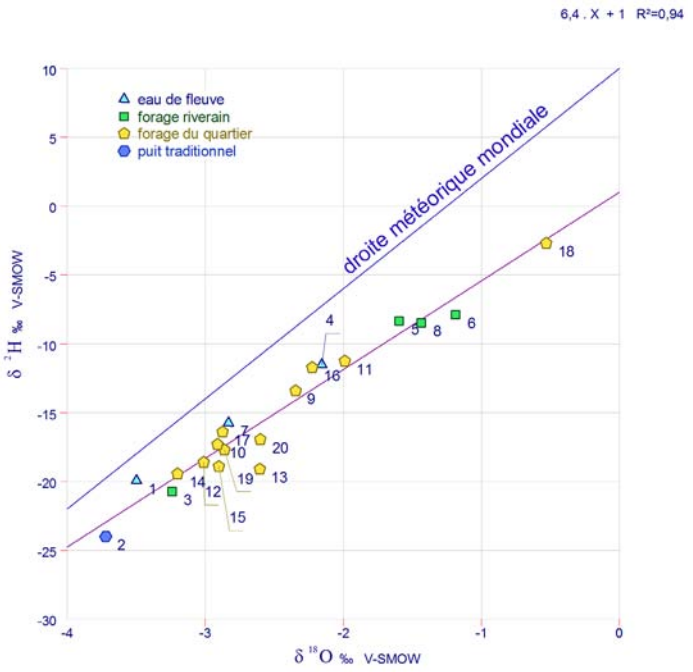
The designations employed and the presentation of material in this map do not imply the expression of any opinion whatsoever on the part of the Secretariats of the International Atomic Energy Agency and of the United Nations concerning the legal status of any country, territory, city or area or of its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

Chad, the fifth largest African country (1284 MKm^2 in size), is located in northern Central Africa, and is mostly a semi-desert country with no coastline. The country has three major climactic zones: the Sahara, a desert zone in the north with less then 50 mm of annual precipitation, the Sahel in the centre where 300 to 600 mm of precipitation falls per year, and the Sudanese savanna zone in the south, which receives over 900 mm of annual precipitation. N'Djamena, the capital, lies in the north-western part of the Chari Baguirmi region, located around the boundary between the Sahelian and Sudanian zones.

Only 23% of the urban population have a drinking water supply (17% in the rural areas), and the city has no functional sewage system. In N'djamena, the population is steadily increasing and is estimated to rise to 800 000 inhabitants by 2013 from about 560 000 living there in 2003 (Kadjangaba, 2007). This rapid increase in population makes it more difficult to meet the demand for safe drinking water. High mortality, especially during the rainy season, has been considered to be largely due to the undesirable drinking water supply situation and poor sanitary conditions; a high rate of diarrhoea and severe risk of cholera always exist. The N'Djamena area is on the Chari floodplain, and the Chari, along with its main tributary, the Logone, recharges groundwater in the area (Schneider and Wolff, 1992). An open canal, which collects domestic sewage, crosses the city from the north to the south. Moreover, many old mines in the outskirts of the city form depressions where water remains stagnant almost permanently.

Much work done

A number of hydrogeological and hydrological studies have been conducted in Chad through international programmes, including, for example, the examination of sedimentation in the Chad basin. Chad has also been participating in two IAEA TC regional projects: RAF/8/036 entitled Sustainable Development of the Nubian Aquifer since 2003, and



The $\delta^{18}O$ vs. $\delta^{2}H$ relationship (courtesy: Ministère de l'Eau; Direction de la Connaissance du Domaine Hydraulique).

RAF/8/041 Formulation of an Action Programme for the Integrated Management of the Shared Nubian Aquifer (UNDP/GEF) since 2006, together with Egypt, Libyan Arab Jamahiriya and Sudan.

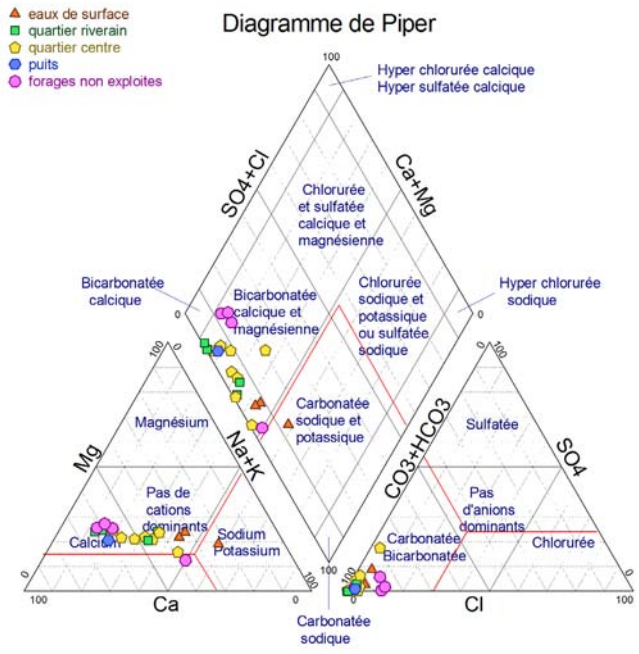
The first national TC project (CHD/8/002), started in 2007, uses isotope techniques to contribute to better knowledge of the aquifer system in the N'Djamena area in order to develop an integrated sustainable water resource management scheme. This project, entitled Contribution of Isotope Hydrology to the Development, Assessment and Management of Water Resources in Chad, has been implemented by Ministère de l'Eau; Direction de la Connaissance du Domaine Hydraulique, Ministère de l'environnement, de l'eau et des ressources halieutiques, Direction de l'hydraulique, and Ministère du pétrole et de l'energie.

Sampling campaign

The sampling campaign was conducted in August 2010 and surface and groundwater samples from different stratigraphic layers were collected at 20 points. These sampling points were selected to cover the entire study area, taking into consideration the lateral variability of aquifers and population distribution/concentration within the city. Two or three different aquifer layers might be hydraulically connected, but the connections were difficult to identify. Most of the water supply to the city of N'Djamena is taken from detrital Quaternary layers where the stratigraphy is complex and which are affected by the changing Chari floodplain level over time. The geology basically consists of alternate layers of clay and sand overlying the thick clay formation of the Pliocene.

The $\delta^{18}O$ and $\delta^{2}H$ values of groundwater samples, except for traditional well water, were within the range of river water values measured in this project or in previous studies and showed the effect of evaporation (Fig. left $\delta^{18}O$ vs. $\delta^{2}H$), which suggests a more predominant role of recharge from river water. The analysis of $\delta^{18}O$ and $\delta^{2}H$ suggests that there are three groups: (a) groundwater from the riverside districts with enriched $\delta^{18}O$ and $\delta^{2}H$ values; (b) water which underwent evaporation to some extent with isotope values within the range of river water during the rainy season or at the time of autumn flooding and; (c) water from traditional wells (point 2) with isotope values close to rain water values. The third group is probably shallow groundwater replenished by rain water in the rainy season in July and early August. Tritium values (0–7 UT) suggest a relative age of water in these groups. River water during the dry season may be slightly older, as river flow during the dry season is sustained in part by groundwater which is more ancient. For the intermediate group, tritium levels varied, suggesting different local flow rates, probably due

'Hydrochemical analysis shows that major ions and many trace elements in deep groundwater are below WHO standards for water intended for human consumption....'



Piper diagram (courtesy: Ministère de l'Eau; Direction de la Connaissance du Domaine Hydraulique).

to heterogeneity of the aquifer. Like traditional well water, Point 6 water also shows the rain water signature, but the evaporation effect seems to be strong. The ^{13}C values (-8.7‰ to -14.6‰) suggest no significant organic pollution, but changes in carbon balance or the bicarbonate level in particular. Hydrochemical analysis shows that major ions and many trace elements in deep groundwater are below WHO standards for water intended for human consumption, except for a few trace elements such as barium, arsenic and zinc at a few sampling points. The results of this project reveal that the deeper part of the Quaternary water body is still relatively well preserved, despite anthropogenic pollution on the surface. However, further studies would be needed to examine the interaction between surface water and groundwaters and between different layers of aquifers in order to avoid over-exploitation of deep water that might drain polluted surface water to deeper levels.

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

ISOtopic GRIdded Rainfall Data Software

The Water Resources Programme got involved with the ISOtopic GRIdded Rainfall Data Software (ISOGRIDS) within the framework of an IAEA Coordinated Research Project (CRP) on Geostatistical Methods of Spatial Isotope Variability to Map the Sources of Water for Hydrology Studies, which terminated in 2010. The software offers many advantages: it is open source, so all software packages are available free though the internet, and it provides a quick and comprehensive tool for implementing the commonly recognized two-step regression/interpolation method established throughout the last decade. Member States can access this software via the IAEA web page; using this they can generate gridded maps of stable isotopes ($\delta^{18}O$, $\delta^{2}H$) in precipitation, drawing from IAEA datasets.

This application was developed by Prof. A. Argiriou and V. Salamalikis of the Laboratory of Atmospheric Physics, Patras University, Greece within the framework of the IAEA. ISOGRIDS is based on the R language and environment for statistical computing and graphics (www.r-project.org), which can be obtained freely under GNU General Public licence (GPL2) for Windows, Unix and Macintosh operating systems. Several additional libraries are necessary to run the application; these are listed in the software manual. The download package is a zipped file including scripts for manipulating deuterium and oxygen-18 values, a user´s manual, and a sample dataset. A text editor is required to work with and edit the script; we recommend Tinn-R (http://www.sciviews.org/Tinn-R/ and http://sourceforge.net/projects/tinn-r/, also distributed under the GPL2).

ISOGRIDS allows the use of different gridded climatic datasets and provides the possibility of using pre-defined as well as custom multiple regression functions and kriging or thin plate splines algorithms for the interpolation of residuals. Please refer to the tutorial for further information on these methods.

 Please be aware that — as with all free software — only limited support can be provided, although establishment of an FAQ site is planned for the future. For further information, kindly contact Luis Araguas at l.araguas@iaea.org or Stefan Terzer at s.terzer@iaea.org. A few examples of the use of these techniques are included in the references below.

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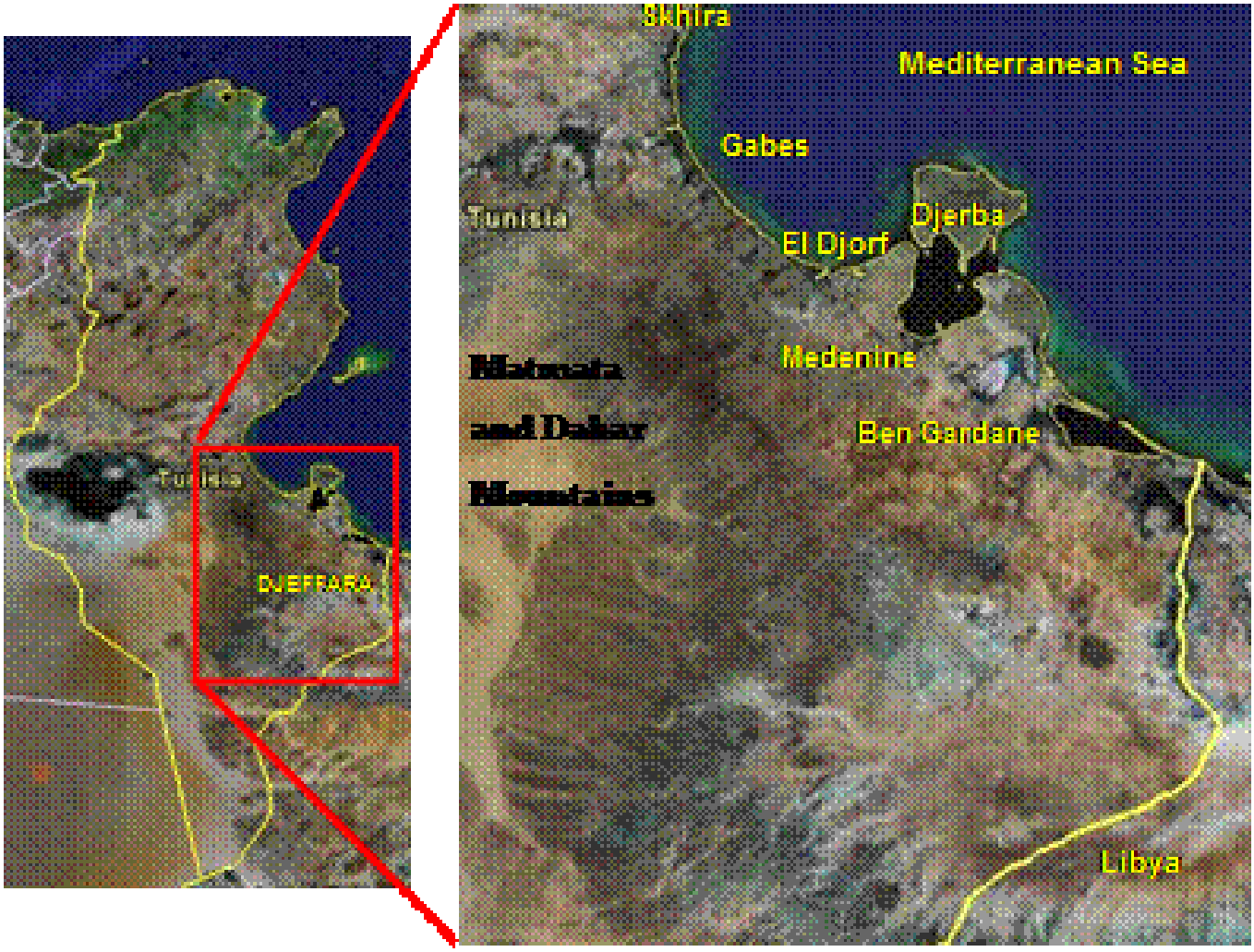
Study of Seawater Intrusion in an Arid Region: Shallow Coastal Aquifer of Tunisia

K. Zouari, T. Rim, Laboratory of Radio-Analysis and Environment, National School of Engineers of Sfax, Tunisia

The isotopic investigation carried out in the Djeffara plain of Medenine (south-eastern Tunisia) has allowed the main processes of water mineralization in shallow aquifer systems to be determined.



The Djeffara plain south-eastern Tunisian coastal aquifer occupies the entire coastal plain.

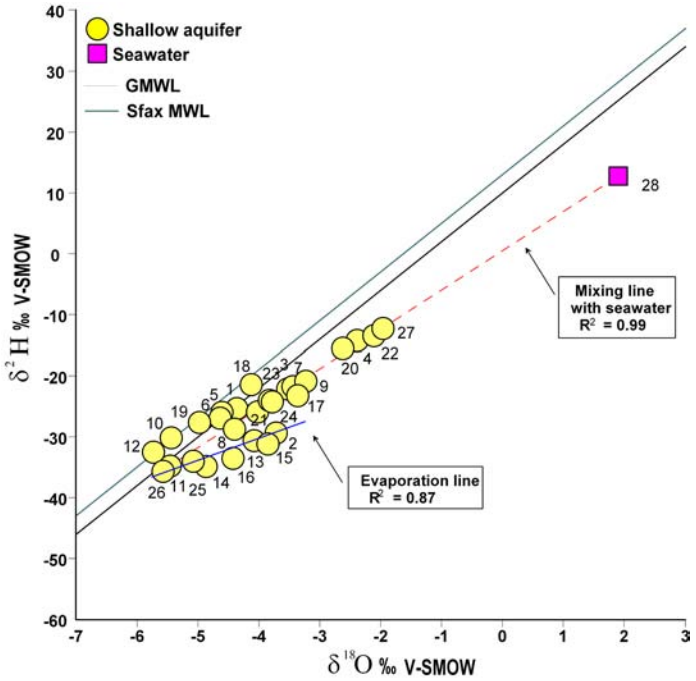
Introduction

Seawater intrusion is one of the most complex problems facing groundwater resources, particularly in coastal semi-arid and arid regions. Urban and economic development and the expansion of irrigated agriculture in south-eastern Tunisia have led to intensive and uncontrolled pumping. Over-exploitation of the shallow coastal aquifer, known as the Djeffara plain south-eastern Tunisia coastal aquifer, has led to the dropping of water tables. Water quality has been seriously degraded and salinity has been increasing in some wells. This study was carried out within the framework of an interregional project (RAF/8/035) financed by the IAEA with the aim of determining the origin of groundwater salinization in the shallow coastal aquifer and identifying areas where groundwater is affected by saltwater intrusion using isotopic methods.

Hydrogeology

The Djeffara basin is characterized by an arid to semi-arid climate. Precipitation is not abundant, mainly occurring during the short cold season. The shallow aquifer occupies the entire coastal plain (see above figure) and is formed by:

— Senonian limestone in the Western part of the basin;



This oxygen-18/deuterium diagram shows that some groundwater samples plot near to the Global Meteoric Water Line (GMWL) and the Regional Meteoric Water Line of Sfax (RMWL).

— Quaternary deposits as alluvial and detrital sediments;

— Sands and clayey sands of Mio-Pliocene age, especially in the coastal fringe.

Tectonic processes control the thickness of aquifer formations, which increase in the direction of the sea. The potentiometric map of the Djeffara shallow aquifer indicates a west-east flow direction from Matmata relief and the El Hamma region towards the Mediterranean Sea. However hydraulic head depressions are observed in the Southern Gabes, and in the El Djorf and Ajim regions where the piezometric levels are below sea level. Migration of the potentiometric isoline at 0 m inside the continent has generated an inversion of the hydraulic gradient in these regions, proving their vulnerability to marine intrusion.

Note

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

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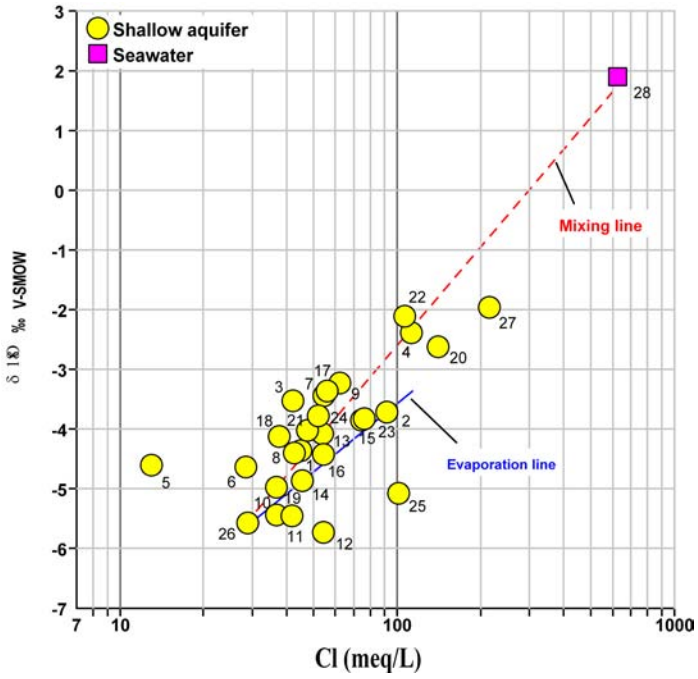
Contributions to the newsletter are welcome.



The Cl-/δ¹⁸O relationship.

Isotope study

Measured stable isotope contents in groundwater samples range from -5.72 to -2.11‰ vs VSMOW for $\delta^{18}O$ and -35.6 to -13.5‰ vs VSMOW for $\delta^{2}H$. The oxygen-18/ deuterium diagram (fig. above left) shows that some groundwater samples plot near to the Global Meteoric Water Line (GMWL) and the Regional Meteoric Water Line of Sfax (RMWL). This suggests that groundwater derives from rain water infiltration. In the top left figure, two linear trends can be distinguished:

(1) The lower line represents an evaporation line which indicates that water is evaporated on the surface or during infiltration in the unsaturated zone before reaching the aquifer, or in the aquifer when water depth level is low. This evaporation is supported by climate aridity.

(2) The upper line (R^2= 0.993) represents a binary mixture between seawater and shallow aquifer groundwater (wells n° 11 and 26). Most samples plotted near this line are characterized by high mineralization and are located in the coastal area.

These two trends are clearly confirmed by the Cl-/δ18O relationship (fig. above). To quantify mixing rates between seawater and the shallow groundwater of Djeffara, the analytical expression that represents the mixing process

between two end members as a function of $\delta^{18}O$ can be used:

$$\delta^{18}O_{sample} = X\ \delta^{18}O_A + (1-X)\ \delta^{18}O_B$$

where X represents the mixing ratio while $\delta^{18}O_A$ and $\delta^{18}O_B$ are the isotopic contents of end members A and B (fresh water and Mediterranean sea water).

Mediterranean Sea water constitutes the first end member (A) (+1.9‰ vs VSMOW); the second end member is represented by groundwater not affected by seawater intrusion (-4.6‰ vs VSMOW). The computed values of seawater contribution vary between 0–41%. They show that the regions of El Djorf, Eastern Djerba Island, Southern Zarzis and Northern Ben Gardane are the areas most affected area by seawater intrusion, where the contribution of salt water exceeds 40%. Compared to their chloride contents, some samples present a low mixing ratio confirming the existence of another source of salinity which can be the dissolution of evaporitic rocks from the sebkhas.

Conclusion

Isotopic investigation carried out in the Djeffara plain of Medenine (south-eastern Tunisia) has allowed the main processes of water mineralization in shallow aquifer systems to be determined:

- Evaporation process proved by stable isotopes contents and supported by climate aridity: it concerns some wells on the El Djorf peninsula and the south-western part of the Zarzis region. This process could occur before or after water infiltration;
- Saltwater intrusion, recorded in most coastal wells.

Stable isotope contents confirm the mixing process between fresh water and sea water, and help to delineate a binary mixing system with two end members. Results indicate that seawater intrusion is pronounced in the region of El Djorf, the eastern part of Djerba and the northern part of Ben Gardane, where the contribution of sea water may reach 41%.

To preserve goundwater resources in the shallow coastal aquifer system of Djeffara and stop contamination by salt water, the following measures are suggested: (1) reduction of pumping for agricultural purposes in the area affected by seawater intrusion or by piezometric depressions; (2) identification of the suitability of artificial recharge.

For further information contact Tuerker Kurttas at T.Kurttas@iaea.org

Meetings in 2011

- Scientific Forum, Vienna, Austria, 20–21 September.
- Technical Meeting on Laser Based Stable Isotope Analysis Users Group Meeting, Vienna, Austria, 9–11 November.
- 2nd Research Coordination Meeting on Use of Environmental Tracer Techniques to Improve Basin-Scale Recharge Estimation, Vienna, Austria, 5–9 December.

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