IAEA
International Atomic Energy Agency

Water & Environment News

Newsletter of Isotope Hydrology Section
Issue No. 22, May 2007

ISSN 1020-7120

http://www.iaea.org/water

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IAEA Water Resources Programme

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From the Section Head . . . . .

This edition of the Newsletter brings together developments at the IAEA in global isotope data management, laboratory facilities and projects related to transboundary groundwater management. For several years we have strived to improve the availability and accessibility of isotope data and I am happy to note that a new web-based platform – WISER – is now ready that allows searching, downloading and manipulation of isotope data from precipitation, surface water, and groundwater sources. GIS functionalities would allow better integration of spatial and/or temporal components into research investigations. A set of gridded values for the GNIP data is also available through WISER. Isotope data from surface water and groundwater studies in Asia, Africa, Latin America and Eastern Europe, collected mostly through IAEA projects over the last 50 years, are also being made available through WISER and as an Atlas of Isotope Data in hard copy. The Africa atlas contains over 10,000 data points. Most of these surface and groundwater data were previously not accessible and were never synthesized and evaluated on a regional or continental scale. Availability of these global data should facilitate the integration of isotopes into regional and transboundary groundwater studies. This edition of the Newsletter contains a number of examples where the IAEA is collaborating with other organizations to fully integrate isotopes for developing resource management and policy options. The 12th IAEA symposium on isotope hydrology will be held in Vienna from 21 to 25 May 2007 and I hope to see many of you then.

Pradeep Aggarwal

Isotope Techniques in the Study of the Guarani Aquifer

By Luiz Amore, Jorge SantaCruz, Ramón Aravena, and Marisol Manzano

The IAEA, through the Technical Cooperation Project (RLA8036), supports the application of isotope tools as part of a large international project which adresses number of key questions in hydrogeology and groundwater uses of the Guarani Aquifer.

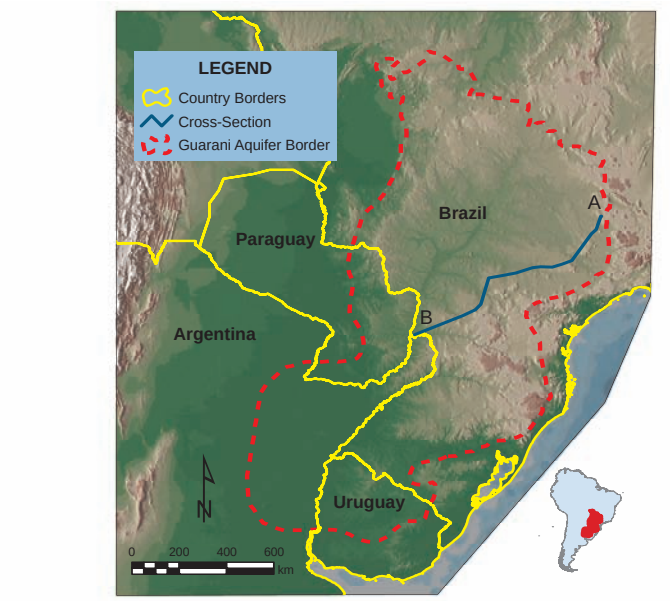


Figure 1. Schematic map of the Guaraní Aquifer System.

Groundwater constitutes around 95% of all planet's fresh and liquid water. It is used by more than two billion people in the world and is considered as the greatest strategic reserve for the next decades. About 26% of the available freshwater in the world is in South America, and more than 50% of its population is supplied by groundwater. Low vulnerability to short climate variations places groundwater in a privileged position when societies' sustainability is evaluated. In spite of this importance, in many of our countries, groundwater resources have not received, nor receive, the attention deserved.

During the last decade, the interest in South America about groundwater has grown but the few available management schemes operating in most countries are no longer adequate. As a result of a lack of adequate management schemes, ground pollution and inadequate well-head protection measures, some overexploitation (greater water extraction than the aquifer's potential) and pollution signs have been observed in some aquifers. If actions are not taken to ensure the preservation of these resources and correction measures are not adopted in critical areas, we will place at risk public and private water supply schemes, mainly in urban centres. The actions to be adopted will depend on the existing technical knowledge of the aquifers and on the countries' initiatives.

The Guarani Aquifer System

The Guaraní Aquifer System (GAS) constitutes a very important groundwater resource in Argentina, Brazil, Paraguay and Uruguay. With transboundary characteristics, it extends from the geologic-sedimentary river basin of Paraná to the Chaco-paranaense river basin (Fig. 1). Of the Guaraní total area – 1 200 000 km^2 – 2/3 is located in Brazil and the remaining 1/3 in Paraguay, Uruguay and Argentina. There are around 20 million inhabitants in the area. Several hundreds of Brazilian cities are totally or partially supplied by the Guaraní Aquifer System. In some sectors, especially in Uruguay and Argentina, hot groundwater extracted from deep wells is mainly used for recreational and therapeutic uses.

The Guaraní aquifer is formed by sandstone layers with an average thickness of 250 m (Fig. 2), deposited during the Mesozoic era (from the Triassic to Lower Cretaceous, 200 - 132 Ma). Nearly 90% of the area is covered by a large concave basaltic lava spill, which confers general characteristics of a regional confined aquifer. In the east and west margins of the geological basin, sandstone outcrops are present, which constitute the aquifer's direct recharge areas. Some sectors are characterized by large geological structures (arcs) and important igneous intrusions. The existing fault and dike systems produced

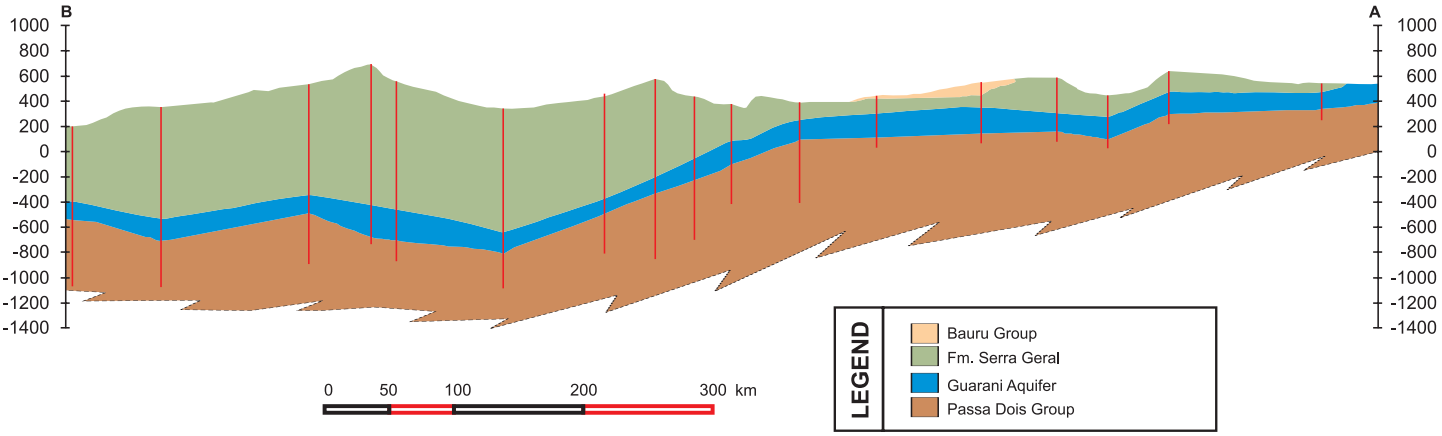


Figure 2. Schematic cross-section of the Guaraní Aquifer System along A–B shown in Figure 1.

discontinuities in the aquifer, which may modify the regional groundwater flow patterns.

The climate is characterized as humid or sub humid, with annual precipitation ranging from 1200 to 1500 mm. The pumping rate of the existing wells varies from a few m^3/h, up to 200 m^3/h in the areas adjacent to the outcrops, and from 200 to 400 m^3/h and even more, in the confined sectors.

Presentation of the Guarani project

The Environmental Protection and Sustainable Development of the Guaraní Aquifer System Project was created to support Argentina (AR), Brazil (BR), Paraguay (PY), and Uruguay (UY) in the elaboration and implementation of an institutional, legal and technical common framework for the management and preservation of the Guaraní aquifer for present and future generations. The project is being implemented for the period 2003–2008, following a well defined list of components and activities.

In the project preparation phase, four pilot projects in some critical areas were identified and studies were initiated. The areas are: a) Concordia (AR) – Salto (UY), to promote sustainable use of the thermal groundwater; b) Rivera (UY) – Santana (BR), bi-national urban centres located on a recharge area of the aquifer; c) Itapua (PY), related to agricultural uses and deforestation; and, d) Ribeirao Preto (BR), oriented towards groundwater management in an urban-rural area with intensive pumping and with a large amount of historical information.

The implementation of the project is possible due to the common agreement signed between the four countries in which GAS is located, a donation of the Global Environmental Facility (GEF), the support of the World Bank (WB), as implementing agency of GEF resources, and the Organization of the American States (OAS), as regional executing agency. The development of technical studies also has the support of the government of the Netherlands, the World Bank program, the German Geological Service (BGR) and of the International Atomic Energy Agency (IAEA).

The four beneficiary countries established a Steering Committee that is constituted by representatives of the institutions responsible for water resources, environment and foreign affairs of each country. In order to support the project's execution, a Co-ordination Group was established, composed by four National Coordinators and one General Secretariat established in Montevideo that implements the activities. In each country, a National Project Executing Unit was structured, that has the support of regional/state units and local support commissions. Since groundwater uses and potential problems are locally based in the four critical areas, it was

established a local management support commission with governmental, private and NGOs representatives and a facilitating consultant was hired.

The Project is organized in seven 'components' with interrelated activities that characterize the Guaraní Aquifer System, based on its particularities and behaviour, its advantage and preservation, its relationship to communities and institutions and main needs for planning and ordering to improve the sustainable management of its waters.

The challenges facing the Guaraní Aquifer System are many and depend, on one hand, on the geological, hydraulic and hydrogeochemical characteristics of the aquifer (technical scientific challenges) and, on the other hand, on the society's and States' capacity to implement a sustainable management plan of the resource (social and institutional challenges).

In the present Project's execution stage, some potential critical topics are under consideration:

a) Risk associated to over-extraction in some wells or set of wells that caused reduction of the water availability and an increase in the operational costs;

b) Risk associated to contamination in some wells or areas of the Guaraní Aquifer System, either from natural or anthropogenic activities;

c) Difficulties to promote exchange of information and institutional strengthening as well as to obtain more participation in the process of groundwater management at national, state and local levels.

Geothermal resources in Paraná and Chaco-Paranaense geological basin region (Guaraní Aquifer region) are due to the natural geothermal gradient of the terrestrial crust. A geothermal sustainable management of the aquifer should avoid some common negative effects related to inappropriate operation of some wells and/or lack of protection measures, such as reduction of volumes; hydrostatic pressure; temperature; or increase in salinity as well as anthropogenic contamination.

Main tasks executed and under execution

A set of Digital Basic Maps of the GAS area at scale 1:250 000, containing all hydrogeological related information (191 sheets) was produced. More detailed hydrogeological information has also been plotted on the Digital Basic Map of the GAS area at scales ranging from 1:50 000 to 1:10 000 in the Pilot Project areas. The main studies under execution are:
a) inventory and sampling of wells and some water bodies of interest;
b) the GAS hydrogeological database;
c) a regional geological-stratigraphic survey of cross sections;
d) a geophysical survey, including seismic reinterpretation, gravimetric, magneto-telluric and geo-electric methods;
e) hydrochemical and isotope characterization of the groundwater in the different regions of the Guaraní aquifer;
f) design and implementation of the Hydrogeology and Hydrochemical Monitoring Network and of the GAS Information System;
g) preparation of thematic maps,
h) regional and local hydrogeology in the 4 Pilot Projects,
i) mathematical modelling of groundwater flow at local level in the 4 pilot regions, and
j) preparation of a technical procedures handbook.

In addition, some other activities have been planned:

a) analysis of new sustainable geothermal uses and analysis of related social aspects.
c) communication and diffusion of initiatives;
d) training plan and institutional strengthening, through the incorporation of trainees and on the job training professionals in the General Secretariat and the companies, specially oriented to management related agencies of the region;
e) participatory meetings and elaboration of the Transboundary Diagnosis Analysis and the Strategic Action Plan, as the main and final project document.

Isotope and hydrochemistry studies

Environmental isotopes are well established tools used for the evaluation of the origin and residence time of groundwater in regional aquifers. The application of environmental isotopes in the Guaraní aquifer started in the 1970s with a local study in the Ribeirao Preto region. Then a regional study that covered most of the Brazilian region of the Guaraní aquifer was carried out in the late 1980s. Since then, a number of isotope data were obtained in some more

Deep boreholes extracting hot groundwater from the Guaraní Aquifer System

or less local studies developed in the rest of the aquifer in Argentina, Paraguay, and Uruguay.

The Brazilian studies found a wide range in the isotopic composition in the groundwater, which varies between -4.9 and -9.6 ‰ for $\delta^{18}O$ and -28 and -67 ‰ for $\delta^{2}H$. These studies also found than the more isotopically depleted groundwaters correspond to the older groundwater, located in the deepest part of the aquifer. This isotopic pattern suggested than the older groundwaters were recharged under cooler climatic conditions than the present ones. The hydrochemical data obtained in these studies showed that groundwater in the recharge area is characterized by low salinity (~10-500 µS/cm) and a Ca-HCO_3 water type, and that it evolves toward a Na-HCO_3 type along the groundwater flow system.

Furthermore, in some areas salinity increases up to 4500 µS/cm in some deep wells close to the Paraná River in the Paraguayan sector. Here, the highest salinity waters show a marked increase in the contents of sulphate and chloride (Na-Cl-SO_4 water type). This pattern is observed only in older groundwater. This information was used to establish the preliminary conceptual model for the mentioned area, which however does not have necessarily to apply to other areas of the GAS.

The new isotope and hydrogeochemical study within the framework on the Guaraní project will contribute to improve the present understanding of the groundwater flow system (origin and residence time), the interaction between the northern and southern part of the aquifer and the role of deeper formations in the salinity of groundwater.

This new study also include the application of new isotope tools, such as ^{36}Cl for the evaluation of residence time of the older groundwater, Sr isotopes to evaluate the interaction between the basalt and the sandstone, and ^{34}S and Br isotopes to evaluate the sources of salinity in the oldest groundwater. In many sectors of the aquifer the historical information is scarce or null, so a great effort must be done to achieve a degree of knowledge comparable of the whole aquifer. To accomplish that, hydrogeochemistry and isotope results must be supported by groundwater flow modelling both at local and regional scales.

Conclusions

The results of this project will be incorporated by the relevant institutes of the four countries, depending on project transparency and direct involvement of professionals from all national related institutions in all activities. Only a management scheme based on adequate knowledge can be sustainable over time, and hydrochemical and environmental isotope studies will contribute to a better comprehension of intrinsic characteristics of the aquifers, groundwater fluxes, as well as recharge and discharge sources and mechanisms of the Guaraní aquifer.

Based on the information generated in the project, the countries will establish some measures for the sustainable management and protection of the GAS. The monitoring network and all information available in a comprehensive GIS are supposed to be continuously updated. Cooperation between countries constitutes a central element to promote the needed changes to support new generations based on a sustainable development model.

For further information please contact Luis Araguas at l.araguas@iaea.org or Andy Garner at a.garner@iaea.org

Environmental Isotope Tracking of Hydrological Processes in the Pampa Plain of Argentina

By Daniel E. Martínez and Héctor E. Massone

Argentinian research group shares the good experience with participation in an IAEA Coordinated Research Project in Isotope Hydrology.

In November 2004, the Isotope Hydrology Section of the IAEA in Vienna organized the first Research Coordination Meeting of the Coordinated Research project on Isotopic Age and Composition of Streamflow as Indicators of Groundwater Sustainability, aiming at the use of isotopes for tracing the amount, pathways and age of the subsurface contribution of groundwater to rivers. Among the 16 research teams worldwide participating in this project from 2004 until 2010 is the Grupo de Hidrogeología del Centro de Geología de Costas y del Cuaternario de la Universidad Nacional de Mar del Plata, working together with the isotope laboratory of the Instituto Nacional de Geocronología y Geología Isotópica in Buenos Aires on the hydrology and hydrogeology of the Quequén Grande basin in the Pampa plain of Argentina. This article briefly describes our experience after two years and highlights the positive impact of the Agency's support on the water knowledge and management in the Quequén Grande basin.

The Argentinian Pampa plain covers the area of approx. 1 500 000 km^2 and it is one of the world's most important agricultural regions, delivering annually about 80 mil. tons of grain. The temperate-humid climate yields about 1000 mm of annual precipitation, which recharges the dominant groundwater resource of the entire Pampa. Important aquifers are located in the basin "Llanura interserrana bonaerense" between the mountainous chains of Ventania and Tandilia, that form the headwaters of the river Quequén Grande. The river has a basin area of about 10 000 km^2, drained through smooth flat slopes of the Pampa eastbound toward the Atlantic ocean (Fig. 1).

The interest in the hydrology of the Quequen basin has been rapidly increasing in the past few decades, due to a series of five big flood events between 1980 and 2002, while the biggest event in 1980 caused inundation of 4 mil. ha of agricultural land, evacuation of 50 000 inhabitants and financial losses that have never been quantified. In 1993, local communities together with authorities of the province of Buenos Aires initiated a Comité de Cuenca del Río Quequén Grande, which was established in 2002 under joint auspices of local representatives, authorities of six communities and the province. One of the key objectives of the Committee is to promote and disseminate knowledge of groundwater infiltration, recharge and subsurface flow, which should help to manage floods, droughts and the groundwater supply in the Pampa communities. This level of knowledge cannot be adequately achieved using standard gauging of rain or discharge and requires employment of hydrochemical and isotopic tracer techniques. In order to share international experience and technical skills on these topics, our Hydrogeology group from Mar del Plata committed to actively participate in the IAEA's Coordinated Research Project (CRP) through the IAEA's annual financial contribution under the Research Contract ARG12884.

Figure 1: The Quequén Grande catchment in Argentina.

The past knowledge of hydrological processes in the Quequén Grande basin suffers from non-existing or poor quality data. At the beginning of the IAEA's

project in 2005, only daily discharge data at the outlet station since 1964 and some meteorological and groundwater level data for the year 2002 were available. They were mostly collected by local inhabitants. When our group became participants in the IAEA's project, we presented our plans to the Comité de Cuenca del Río Quequén Grande, who immediately considered it as a priority activity and provided fieldwork logistics support. Collaboration was also established between our group and the isotope laboratory of the Instituto Nacional de Geocronología y Geología Isotópica in Buenos Aires, which covers the isotope analysis from the Quequén Grande basin and helps overcome the all to frequent barrier in many isotope hydrology projects in the developing countries — easy availability of isotope analysis.

Since the beginning of the project our group equipped the Quequén Grande basin with four additional rain collectors for monthly isotopic analysis, starting with weekly sampling of river water at five sites, and trimestral sampling of groundwater (Fig. 2). Five hundred samples were analyzed so far for water chemistry and three hundred samples for stable water isotopes and Tritium. Thanks to the Comité de Cuenca del Río Quequén Grande, two additional piezometers have been installed, and a setup of three additional limnigraphs and an additional meteorological station have been approved.

The impact of the project has been extended to other countries in Latin-America. A fellowship grant was offered by the Agencia Nacional de Promoción Científica y Tecnológica of Argentina for a PhD student to participate in the project, and it was assigned to Mr. Mauricio Quiroz Londoño from Colombia, who is now successfully developing the third year of his PhD studies. Between June and November of 2006, Ms. Teresita Betancur Vargas from Colombia was working on the project with our group in the framework of her international internship required in her PhD studies at the Antioquía University in Medellín.

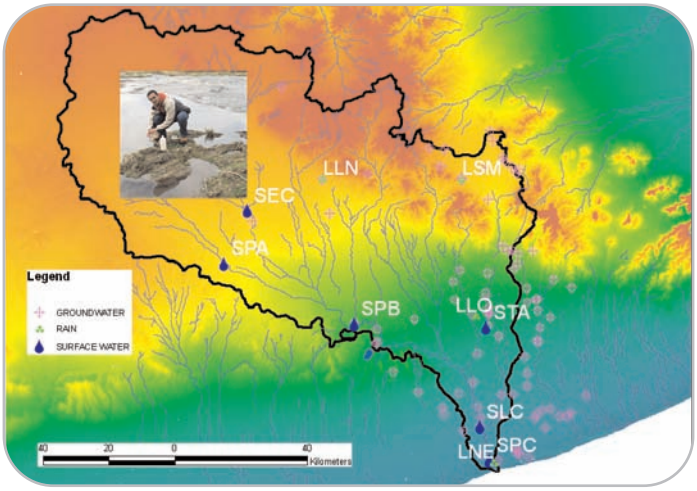


Figure 2. Sampling streamwater at the site SEC

Today, two years after the start of the project, there is an enormous increase in knowledge and local consciousness about the groundwater hydrology of the Quequén Grande. All geographical, geological, hydrological, meteorological, chemical, and isotope data are stored in a geo-referred database, which now includes about 100 000 data values and is available and highly appreciated by local and regional users. Isotopes contributed to the preliminary delineation of hydraulic conductivities, providing information on groundwater travel times in various parts of the aquifer. The travel times will be part of a conceptual model of stream/aquifer interactions, which is our final objective.

Our group frequently shares knowledge through educational talks in local small schools and regular meetings with the Comité de Cuenca del Río Quequén Grande. Results of isotopic observations in the Quequén Grande will be presented at the IAEA's Isotope Hydrology Symposium in May 2007. Our participation in the IAEA's CRP is already considered a big success, and has substantially enriched the scientific knowledge of the hydrology of the basin and promoted links to local and regional institutions, which are using the results in integrated surface water and groundwater management, mitigation of floods and droughts, and sustainable groundwater use. The Hydrogeology group of the Mar del Plata University is looking forward to further collaboration with the IAEA and all our partners in the catchment of Quequén Grande, and wishes to other isotope hydrology groups in IAEA's Member States an equally fruitful participation in the IAEA's Water Resources Programme activities.

For further information please contact Tomas Vitvar at t.vitvar@iaea.org

WISER, New GIS-based Online Software for Data Analysis, Visualization, and Electronic Retrieval

Powerful new features and major enhancements of tools, information, and isotope data have been added to the IAEA Water Resources Programme webpage.

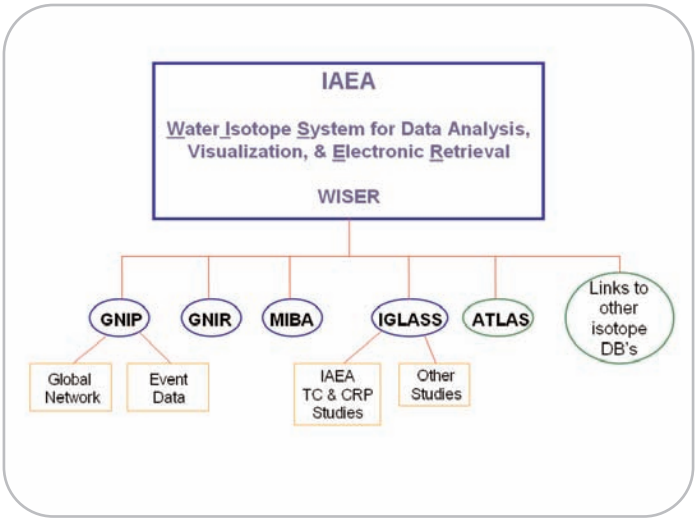


Figure 1. Structure of the IAEA Water Isotope System (WISER). Blue indicates a primary database within WISER, orange a secondary database, and green indicates other resources.

WISER

In March, 2007 a new online application was incorporated into the IAEA isotope hydrology website. The new software application is called WISER, which stands for Water Isotope System for Data Analysis, Visualization, and Electronic Retrieval (WISER, Fig. 1). WISER is an integrated, computer-assisted mapping environment for the dissemination and visualization of hydrochemical and isotope data. It offers a number of possibilities for presenting and analyzing geo-referenced isotope and hydrochemical data from around the world. WISER is intended to promote broader and more extensive use of isotope tools to understand functioning of the water and biogeochemical cycles. Built in collaboration with the University of Vienna, this primarily GIS-based tool allows graphical accesses to four primary databases, and supersedes the older non-graphical ISOHIS data retrieval interface. The new system allows the selection of sampling sites through a map interface and or through the use of a number of searching criteria. For example, the type of data desired can be specified (e.g., precipitation, river water, and groundwater). Data can be plotted in the application and then downloaded for further processing with only a few clicks. For example, the new IAEA publication Atlas of IAEA projects on Isotope Hydrology in Africa has been produced and the entire data set is available in WISER.

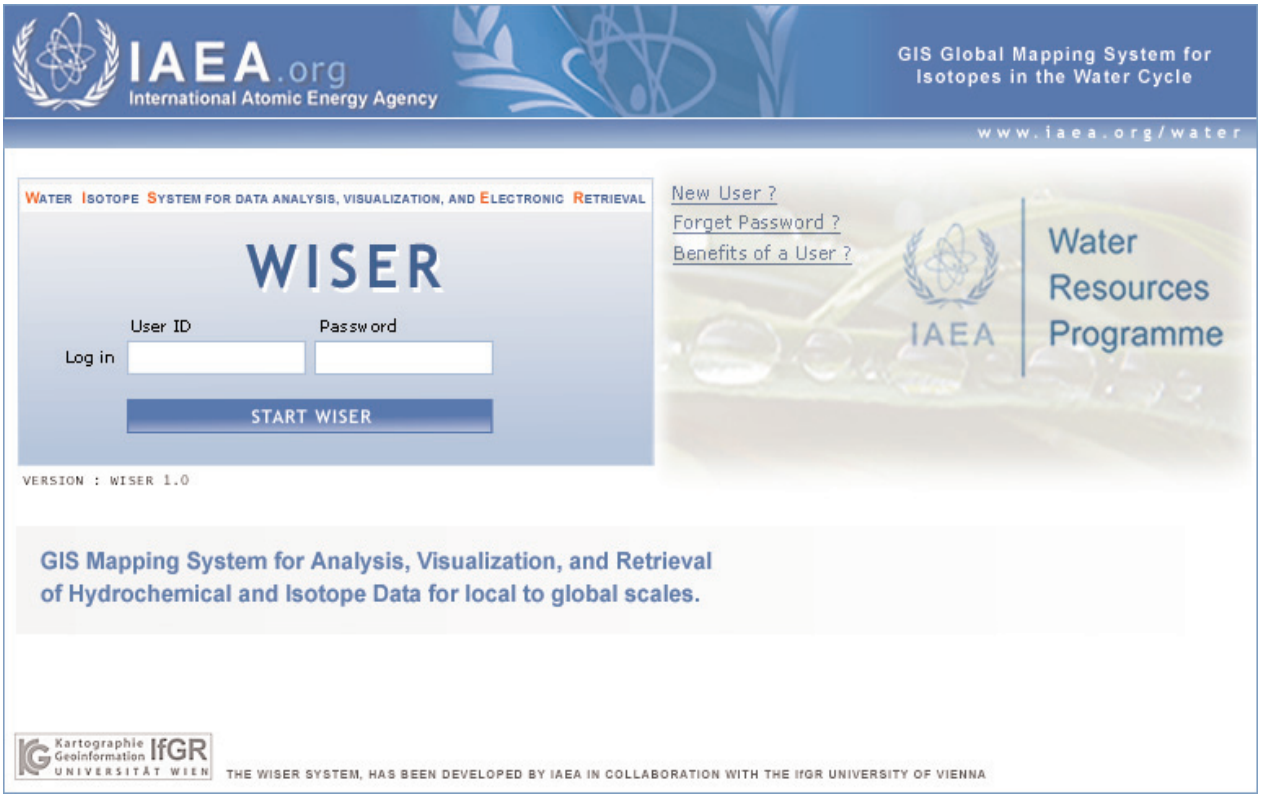
The four primary databases within WISER (Fig. 1) contain isotope and related hydrological data for several water types such as atmospheric vapour, groundwater, plant water, precipitation, river water, and soil water. These databases are briefly described below:

Global Network of Isotopes in Precipitation (GNIP)

GNIP has been operated since 1961 by the IAEA with the support of the World Meteorological Organization (WMO). The objective of GNIP is the systematic collection of data on the isotope content of precipitation (i.e., δ^2H, $\delta^{18}O$, and ^3H) and associated meteorological data at a global scale. The previous and primary focus has been on water resources applications; however this has expanded recently to support other fields such as atmospheric circulation modelling, monitoring climate change, paleoclimate studies, ecological studies, and forensics/food traceability. More than 110 000 records are available in this database. It contains isotope data of precipitation samples collected both on a monthly and event basis. WISER provides access to the statistical treatment of the isotope and meteorological data from stations collecting samples on monthly basis.

Global Network of Isotopes in Rivers (GNIR)

The objective of GNIR is to provide a global network of isotope data from major rivers. Because rivers integrate and record effects from multiple types of



Access WISER webpage through http://www.iaea.org/water

simultaneously occurring environmental changes, river monitoring networks should be an effective means for identifying impacts of change at large scales (e.g., basin to global) and for quantifying effectiveness of mitigation/management responses. About 15 000 records will be available in GNIR in the next few months.

Moisture Isotopes in the Biosphere and Atmosphere (MIBA)

The objective of MIBA is to complement GNIP by providing data on additional components of the water cycle to better support isotope applications involving the water cycle, carbon cycle, and climate. It includes data on the isotopic composition of water in plant leaves, stems, soil, and atmospheric vapour. Preliminary data are available since 2004 in the WRP webpage.

Isotopes in Groundwater, Lakes, Springs, and Streams (IGLASS)

This database provides access to isotope and hydrochemical data (e.g., basic water chemistry and chlorofluorocarbon data) from studies conducted at local and regional scales. The IAEA has made a significant investment to compile both electronic and hardcopy historical data from IAEA Technical Cooperation Projects (TC) or Coordinated Research Projects (CRP), and these form the major part of IGLASS. Because these projects typically focus on developing nations, IGLASS provides access to isotope data from areas where data is often limited or nonexistent in the published literature. An additional secondary database contains isotope data from non-IAEA sponsored projects. IGLASS contains a variety of isotope and geochemical data (especially from groundwater, lakes, springs, and rivers) collected since the 1960's. Potential users are encouraged to explore the features in WISER through the IAEA Water Resources Programme website at **http://www.iaea.org/water/**.

For further information please contact Brent Newman at b.newman@iaea.org or Luis Araguas at l.araguas@iaea.org

LabData: Database and Laboratory Management System for Isotope Hydrology Laboratories

In 2006 a new Database and Laboratory Management system was installed in the isotope hydrology laboratory. This software is a very versatile multi-purpose tool able to handle workflow and data storage of geochemical, geochronological and isotope laboratories with special post processing capabilities for isotope hydrology. The open source code is available for other laboratories.

The IAEA Isotope Hydrology Laboratory (IHL) has switched to a new database and laboratory management system. This transition was necessary since the former database system SaDat, based on DOS and DBase, did not fulfil the requirements any more. Some of these missing requirements were: SaDat included no results obtained for standards. Therefore assessment of quality assurance information was not possible and had to be handled external to the result database system. The number of possible result values of the same kind (e.g. ^{18}O) per sample was limited to a maximum of three in SaDat. There was no bookkeeping of sub-samples like e.g. stable isotope, tritium, ^{14}C, CFC, noble gas sub-samples from the same well. SaDat included no post-processing, like for instance the computation of average values for multiple measurements. It was not able to deal with the comparable complex data obtained by the new noble gas facility.

Since one of the present members of the Isotope Hydrology Section and Laboratory (Axel Suckow) had developed a database system for his former employer, the Leibniz Institute for Applied Geosciences (GGA), this was considered among other database systems and tested. The software, called 'LabData', was found to cover all tasks SaDat had covered. Additionally LabData was found to fulfil all the requirements mentioned above and several more. Therefore it was decided in late 2005 to import the whole existing digital data in SaDat to LabData, covering the IHL history since 1989. After thorough testing of system performance and some minor adjustments concerning details of laboratory workflow in the IHL, LabData became fully operational as database and laboratory management system for the IAEA Isotope Hydrology Laboratory in the second half of 2006.

With a MS SQL Server® back end and a MS Access® front end and graphical user interface, LabData is a modern client-server database system, running under Microsoft Windows® family. The code is not specialized to any application or technique: The data model was used successfully for geochemical, geochronological and isotope hydrological laboratories. Any kind and any number of samples, with any number of SubSamples per sample and any number of measurements per SubSample can be stored. New techniques introduced to a laboratory do not require changes in the data model but just a new entry in an existing table. It covers the laboratory workflow from the moment samples enter the lab to the final result, including attribute data like the interdependence with projects, exposures (wells), and geographical data. Additionally it covers several post-processing methods necessary for the interpretation of isotope hydrological data like correction formula for radiocarbon or tritium-helium groundwater ages and lumped parameter models similar to the FlowPC and MULTIS codes. Algorithms to deconvolute heavy noble gas concentrations to determine infiltration temperatures and excess air are in preparation. Data can be imported from and exported to Microsoft Excel®.

While LabData is a multi-purpose system flexible enough to cover many laboratory applications, it is of course not a priori able to perform any kind of raw data evaluation. For instance renormalization of stable isotope raw data as they come from a certain mass spectrometer or laser device to the VSMOW/SLAP scale is not yet included. This important example will be one of the future developments. At present LabData can perform the raw data evaluation of proportional gas counters (from raw counts to % ^{14}C or TU) and to handle isotope enrichment of tritium samples with algorithms developed for the GGA-Institute, Hannover. It also cooperates smoothly with the NobleControl software controlling the new IHL noble gas facility (see this Newsletter).

For further information please contact Axel Suckow at a.suckow@iaea.org

News in Brief

Awards, Presentations, and Publications

Michelle Davin received an IAEA Merit Award for 2005 recognizing her good performance and contributions to the Isotope Hydrology Section.

Luis Araguás Araguás, Pradeep Aggarwal, Ornanette Azucena, Andy Garner, Andrew Herczeg, K.M. Kulkarni, and Türker Kurttas of the IAEA Isotope Hydrology Section received an IAEA Outstanding Teamwork Award for their work on the Global Water Challenge Event during the 2005 IAEA General Conference.

Pradeep Aggarwal, Andy Garner and K.M. Kulkarni received an Department of Nuclear Sciences and Applications Award for Best Public Information and Outreach in 2005, for the new IAEA Water Resources Programme Information Materials (folder, brochure, fact sheets, etc.)

Preliminary results from a new water isotope laser method were presented by Pradeep Aggarwal at the December, 2006, American Geophysical Union meeting. A poster was presented which describes this promising new technology for rapid and less costly analyses for $\delta^{18}O$ and $\delta^{2}H$ on water samples.

An article discussing the importance of isotope hydrology appeared in the January 2007 edition of the Sueddeutsche Zeitung science magazine, Wissen. The article describes the IAEA's role in addressing local to global scale water problems and how isotopes can provide unique hydrological and geochemical insights.

Departing Staff Member

Mr. Shawan Dogramaci joined the Isotope Hydrology Section in September 2006. He was formerly a technical staff member in the Western Australian State Department of Water, Australia. His interests included application of isotope techniques in tracing hydrological processes in large scale basins and the salinisation processes in arid and semi arid regions. Mr. Dogramaci worked on incorporation of data into the ISOHIS (Isotope Hydrology Information System) database and preparation of the isotope atlas for the African Continent.

New Staff Member

Mr. Brent Newman joined the Isotope Hydrology Section in October, 2006. He was formerly a technical staff member in the Earth and Environmental Sciences Division at Los Alamos National Laboratory, USA. His interests include contaminant hydrology and the application of environmental tracer methods (including isotope techniques) to understand processes in the vadose zone and groundwater, especially in arid/semi-arid regions. He has also been involved in ecohydrological studies. Ecohydrology involves the interface between biological and hydrological processes, and understanding the links between these systems is critical for addressing many of the important environmental change/disturbance problems that we face today. Isotope techniques can be very revealing about processes that occur at this interface. Mr. Newman will be working on water issues in Africa and Asia.

Regional Training Courses

A regional training course on Isotope Hydrology with a focus on case studies in Central America was organized under the framework of regional project RLA8040 in Panama, October 16–22. This activity included a standard course of isotope hydrology, hydrochemistry, and hydrogeology, combined with a workshop on interpretation of respective case studies of each country under assistance of regional experts. This scheme was highly appreciated by the participants because it allowed immediate application of the taught methods to project problems. It was recommended that this model be followed in further educational activities.

Meetings

A joint Research Coordination Meeting of regional projects RLA8038 and RLA8040 was conducted in San Salvador, 29–31 May 2007, to review and progress and adjust workplans for 2006. The objective of RLA8038 is to support the establishment of a management plan for an integrated watershed management programme in the transboundary Trifinio region (El Salvador, Guatemala, Honduras). RLA8040 focuses on an integrated groundwater resources management system within areas of intense geothermal water exploitation. Because of the thematic similarities, joint implementation of both meetings was appreciated by the participants. It allowed them to plan and coordinate common activities, such as capacity building or laboratory analysis, in an efficient manner.

A meeting was held in late 2006 with the International Joint Commission on the Great Lakes (North America). The meeting discussed how the IAEA Isotope Hydrology Section can partner with other research institutions studying water/atmosphere interactions in the Great Lakes area. Isotope methods appear to be very promising for understanding water balance issues of this large inland lake system, and for testing and calibrating regional atmospheric models.

The GNIP steering committee met in Vienna from 6 to 7 November 2006 to discuss the status of the network and ideas for improving global spatial coverage. This meeting was immediately followed by a consultants meeting on the Establishment of National Networks for monitoring isotope contents in precipitation. Held in Vienna from 8–10 November 2006, it was attended by representatives from India, Morocco, Thailand, Turkey and Venezuela. The main objective was for participants to obtain basic information on the Global Network of Isotopes in Precipitation (GNIP) programme, including relevant operational aspects, so that participating countries could launch initiatives leading to the establishment or reactivation of National Precipitation Networks within GNIP. As a result of the meeting, several precipitation monitoring stations (and runoff in some cases) for isotopes have been established in the mentioned countries.

A WHYMAP consultant meeting was held at the Isotope Hydrology Section at the IAEA 20–21 November 2006. WHYMAP is a project to produce a World HYdrological MAP which describes the distribution of different types of groundwater aquifers worldwide. In addition, map coverage of global diffuse recharge estimates will be included. The IAEA is a partner with UNESCO for the development and production of WHYMAP. The first edition of WHYMAP is intended to be released later in 2007.

The important roles of wetlands have received political and scientific attention in recent years in water resource management, environmental protection, and conservation. The first research coordination meeting for coordinated research project on Isotopic Techniques for Assessment of Hydrological Processes in Wetlands was held in Vienna, Austria, from 4 to 8 December 2006. The meeting was attended by nineteen participants who conduct wetland-related research using isotope techniques in Africa, Asia, Europe, and North and South America. Following the presentations on wetland research projects by the participants and on the water resource programme in IAEA by the staff members in the Isotope Hydrology Section, the participants discussed developing internal CRP cooperation and how the studies should contribute to improved management of wetlands and water resources in general. The second CRP meeting is planned in 2008.

New Developments

Substantial progress has been made toward completion of the Isotope Hydrology Atlas of Africa. This activity has been a significant effort to document the many years of IAEA Water Resource Programme technical cooperation work and data from the African continent. The atlas is in final production and it is anticipated that it will be released by the third quarter of 2007. It will be available in hard copy and through the Water Resources Programme web-site.

The use of isotopes to improve understanding of groundwater/river interactions, river water balance and human impact on river discharge under present and future climate conditions was the subject of the CRP completed in 2006. Seventeen research teams provided a set of novel methods on the interpretation of isotope data in rivers and elaborated a rationale for the continuous collection of river isotope data in the Global Network of Isotopes in Rivers (GNIR). This

worldwide data collection highlights the role of isotopes in quantitative constraints of hydrological processes that are difficult to obtain through conventional discharge gauging, and contributes to a sustainable management of river basins. The data will be publicly available through the water resources program website and stored in the GNIR database. An IAEA technical document is also in progress.

The IAEA Water Resources Programme has recently completed an instructional video on water sampling for isotopes and geochemistry. The video provides a step by step introduction to proper techniques and methods for collecting a variety of isotope and geochemical water samples, and also includes an overview of laboratory methods for analysis of isotopes. It is intended to be a learning tool for those conducting field work in Member State projects, for students, and those interested in a better understanding what is required for proper field collection of samples for isotope hydrology studies. The video will be available in 2007 through the IAEA Water Resources Programme website and through CD-ROM.

Meetings in 2006

• Fifth meeting of the scientific steering committee of GNIP, Vienna, 6–7 November 2006

• Consultants meeting on the establishment of national networks for monitoring isotope contents of precipitation, Vienna, 8–10 November 2006

• Scientific steering committee meeting of global estimation of groundwater recharge for WHYMAP, Vienna, 20–21 November 2006

• First research coordination meeting of the CRP on geostatistical analysis of spatial isotope variability to map the sources of water for hydrological studies, Vienna, 27–29 November 2006

• First research coordination meeting of the CRP on the use of isotopes in understanding hydrological cycle in wetlands, Vienna, 4–8 December 2006

• Technical meeting of laboratory managers active in external analysis network (Isotope Hydrology Analysis Network, IHAN), Vienna, 11–13 December 2006

Meetings in 2007

• Second coordination meeting on use of isotopes and geochemical techniques in the study of artificial recharge in groundwater (ARASIA3), Dubai, United Arab Emirates, 29 January–1 February 2007

• IAEA/ GEF IW Learn/ USGS Aquifer Exchange Study Tour, USA, 16–26 April, 2007

• International symposium on advances in isotope hydrology and its role in sustainable water resources management, Vienna, 21–25 May 2007

• Research coordination meeting on isotope methods for the study of water and carbon cycle dynamics in the atmosphere and biosphere, Vienna, 21–25 May 2007

• Sixth meeting of the scientific steering committee of GNIP, Vienna, 21–22 May 2007

• Research coordination meeting on optimization of irrigation water use efficiency by using isotope techniques to evaluate water flux below the root zone in flood and drip irrigation, Vienna

• Research coordination meeting on optimization of irrigation water use efficiency by using isotope techniques to evaluate water flux below the root zone in flood and drip irrigation, Vienna

• Consultants meeting on the use of isotopes in the assessment of river-aquifer interactions: A case study of the tri-country Austrian-Slovak-Hungarian part of the Danube basin, Vienna

• Research coordination meeting on isotope age and composition of streamflow as indicators of groundwater sustainability, Vienna

• Technical meeting on the development of isotope methodologies for water quality assessment and management, Vienna

Editor's Note

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

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Contributions to the newsletter are welcome.

Extension of the Isotope Hydrology Laboratory

Two tritium electrolysis systems with wall-mounted gas bubblers and safety gas dilution system.

Location of two mass spectrometers and the infrared laser instrument for water stable isotope analysis.

In a major extension of the Isotope Hydrology Laboratory premises, last year 200 m^2 space were added to the laboratory area, bringing the available space close to 800 m^2.

This responds to a significant broadening of available laboratory techniques and instrumentation. The new Tritium/^{3}He laboratory, after nearly four years of scientific development and construction, is close to finalisation of the initial implementation phase, with first gas samples from a field study being analysed successfully (see separate article). The associated dissolved gas extraction system necessary for analyses from conventional copper tube water samples is just under testing. Additional components like low-level tritium analysis and heavy noble gases analysis will be added in the next years.

A continuous flow mass spectrometer was installed last year (GVI Isoprime with EA and HT-EA). This instrument is optimised for analysis of small water samples using HT-EA and will be used for routine water analysis at the laboratory.

An infrared laser spectroscopic instrument for stable isotope water analysis was installed and tested (Los Gatos Research). This system shows a performance not much different from the CF-MS and will also be used for complementary routine stable isotope analysis.

In the new laboratory area, a central technical facility was created which hosts now the complete existing tritium preparation laboratory with both two electrolysis and two distillation systems. The safety features for electrolysis operation and robustness of the cooling system were improved. Two stable isotope mass spectrometer are located in the same central room (Finnigan Delta Plus dual inlet mass spectrometer with 48 port water equilibration line, as well as GVI Isoprime continuous flow mass spectrometer with both EA and HT-EA). In addition located there is an infrared laser spectroscopic system (Los Gatos Research) for water stable isotope analysis. A common gas supply for all instruments and common gas exhaust system facilitates their operation. A common storage room for all stable isotope reference materials improves significantly the logistics for storage and handling of reference materials. Enlargement of the existing storage rooms is already implemented for the anticipated future needs for sampling containers of the new T/^{3}He system and supplementary equipment.

To complete the re-structuration of the laboratory, all major equipment is now concentrated in only four laboratory rooms. A third stable isotope mass spectrometer (Finnigan MAT250) is located in the Tritium/^{3}He laboratory as well as the CFC gas chromatograph.

This made it possible to create new separated office space for all staff of the Isotope Hydrology Laboratory, significantly improving their working conditions.

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The Vienna Facility for Noble Gas Measurements in Groundwater

The first step of installation of a new Noble Gas facility for Isotope Hydrology applications in the member states is completed. The system is capable of measuring helium and neon concentrations and their isotopic composition in water samples. Some of the goals and concepts are explained. The next steps will be the measurement of the heavy noble gases Ar, Kr, Xe, and tritium measurements via ingrowth of ^{3}He.

Noble gases have proven to be a very important tool in modern isotope hydrology. The T/^{3}He dating method of groundwater is probably the most known and prominent noble gas method in Isotope Hydrology. In contrast to Tritium alone, which for principal reasons is not able to distinguish recharge after 1980 from recharge after 1990 or 2000, the T/^{3}He dating method allows to compute apparent ages in this time range. But Noble Gases have a much wider range of applications: since uranium and thorium is contained in nearly all kinds of rocks and since their decay produces alpha particles (helium ions), helium can be used as an age tracer in groundwater beyond the time scale of the application of tritium. The heavy noble gases neon, argon, krypton and xenon can be used to derive the conditions of recharge, such as temperature, altitude and salinity. This are very useful constraining parameters both to derive the origin of groundwater and to better correct for excess air in T/^{3}He dating. For very old waters ^{40}Ar, produced from radioactive decay of potassium (^{40}K) can be used as an age tracer. Finally the detection limit of tritium can be improved by approximately an order of magnitude as compared to radiometric methods using the ^{3}He ingrowth technique. All these applications together make noble gases one of the most versatile tools in modern isotope hydrology.

Early in 2003, the IAEA began the installation of a noble gas facility within the Isotope Hydrology Laboratory. It is the first one not situated in a university environment but dedicated to water management applications within projects in the Member States. The IAEA laboratory is one of only a dozen laboratories worldwide able to carry out similar determination. Experience from these laboratories has shown that typical installation time from purchasing a mass spectrometer capable to measure the ^{3}He/^{4}He ratio to the first water measurements for neon, helium and the ^{3}He/^{4}He ratio is three years. Reasons for this comparably long installation time are that every machine in this scientific field is still unique and that the techniques of measurement automation and software control still vary drastically within a time span of some years. Consequently installation of any noble gas facility has to occur in several steps, usually starting with the most prominent application, the T/^{3}He groundwater dating.

We studied some of the established approaches of noble gas measurement in water, rock and gas samples and tried to combine as many well proven techniques as possible to reach the targets defined above. All approaches together can be summarized in the following sample preparation and measurement steps:

separate gases from water;
separate noble gases from reactive gases;
separate the noble gas species from each other (He, Ne, Ar, Kr, Xe);
measure each noble gas component and its isotopic composition in a mass spectrometer;

The goals stated above define the targets for the final state of the system to be installed: it has to be capable of measuring the ^{3}He/^{4}He ratio which implies that a mass spectrometer is necessary capable to resolve masses 3.016 (^{3}He) from 3.022 (HD and H_3). It should be able to handle any type of sampler routinely used in groundwater studies, may it be the typical pinch-off copper tubes or passive samplers. In contrast to other installations dedicated e.g. to oceanographic samples it has to be able to handle samples with higher load of reactive gases like CO_2, CH_4 etc. It also has to be able to measure samples with helium contents several orders of magnitude above solubility equilibrium. It should be able to measure as many of the heavy noble gases argon, krypton and xenon as possible. The larger sample numbers per site in modern studies makes a high sample throughput desirable. This in turn needs high degree of automation with simultaneous parallel

measurement of different gas components in different mass spectrometers and also points towards an off-line extraction system.

After an investment of nearly US $1 000 000 and four years of scientific development, in early 2007 the facility consists of a MM5400 sector field mass spectrometer plus two quadrupole mass spectrometers (QMS) and a very recently finished off-line extraction system for 10 samples in parallel in one run. An eight-fold multiport and a calibration system using aliquots of air is connected to a noble gas purification system that consists of traps and getters and one QMS. This purification system will be dedicated to measuring the heavy noble gases, but it can be bypassed to a cryo purification and cryo charcoal trap system similar to oceanography-dedicated installations. After these cryo traps a precise spinning rotor gauge (SRG) together with a system of split volumes allows us to determine the absolute helium concentration and to partition large helium amounts. This ensures that the signal range for $^{3}He/^{4}He$ determination in the MM5400 sector field mass spectrometer is less than a factor of five for ^{4}He. Simultaneous to the helium measurement, the neon fraction is desorbed from the cryo trap, the absolute neon concentration is measured with the SRG and the $^{20}Ne/^{22}Ne$ isotopic ratio determined in the second QMS.

The measurement system is controlled by our own software, 'NobleControl'. It is a very modular code in LabView that runs under MS Windows XP and can be easily adapted to new hardware. Very flexible control over the measurement process itself is possible in NobleControl with a script language having the typical syntax features of present day high-level programming languages including Variables, Repeat and While loops and nested blocks. To save preparation time and enhance sample throughput it uses parallel processing of several command queues and the communication between these tasks by messages. A typical sequence in our actual approach comprises seven command queues. They simultaneously control the measurements of the three mass spectrometers, the gas inlet, the cryo purification, manual commands and a master dispatch queue. All system state parameters like pressures, valve states, temperatures, MS signals etc. are stored at user-defined intervals and can be displayed during the run. The typical amount of data produced from a one-day run is around 20 MByte as ANSI text files. Post-processing is achieved using a noble gas dedicated sub-system of the LabData laboratory management and data-base system (see this Newsletter). Both NobleControl and LabData are open source codes and the entire software is available free of charge for other groups.

To date we have achieved an internal reproducibility, defined as the standard deviation of the efficiency (signal/ccSTP) of air aliquots through the whole measurement process over six weeks, of better than 1.5% for ^{3}He and better than 1% for ^{4}He, ^{20}Ne, ^{22}Ne. A typical gas inlet (reference air split or unknown) is processed through the whole system within 45 minutes. This is comparably slow for helium and neon measurement only and can be further optimized. But it is to be expected that during future runs including the measurement of heavy noble gases one hour will be a typical time for the whole process. We aim for the full processing of noble gases of eight unknowns within an automated 24 h run. The system is the first one worldwide that has demonstrated to measure helium-neon ratios up to 100 000 times the atmospheric value in fully automated mode. Such high amounts of helium are splitted automatically where each split reduces the helium amount by a factor of 2.62 and needs five minutes. Test measurements using passive samplers equilibrated under laboratory conditions show to agree well with the expected values of helium and neon concentration and to better than 1% and 0.5% respectively with the expected helium and neon isotope ratio. The first water samples to date are processed by the off-line extraction system. The next steps are the investigation and optimization of parameters of the extraction system (first half of 2007) followed by the necessary steps to measure concentrations of argon, krypton and xenon in automated mode.

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IAEA and Transboundary Aquifers: Highlight on the Northwest Sahara Aquifer System

IAEA supported investigations are leading to a better understanding of this important shared aquifer resource in the Northern African countries of Algeria, Libyan Arab Jamahariya, and Tunisia.

Isotopic techniques predict water availability

Every year, the pressure to use groundwater resources from underground aquifers increases across the globe, especially in arid regions. Rising human populations, demands from thirsty industrial and agricultural sectors and a global decline of accessible and clean surface waters, in part due to climate change, are all drivers for national and local water managers to bet their hopes on underground reservoirs.

Many of these aquifers are transboundary — shared by two or more countries. And sometimes, countries sharing aquifers are not always the best of friends. That's not great news when the action of one country, for example the over-abstraction of groundwater, leads to a rapid depletion of groundwater throughout the aquifer including that in neighbouring countries. It becomes an even bigger problem if the aquifer is not being naturally recharged over time, say from rain or adjacent rivers.

Experience now shows that improving the wise management of shared aquifers depends on two key strategies. The first is to enhance cooperation between the countries sharing the aquifer, for example from exchanging information and lessons learned. Another example is to create a regional legal framework such as a joint convention that will help prevent negative impacts by one country affecting another. The second strategy is to gain a better understanding of how the aquifer works through the most advanced science available – namely, through the use of cutting-edge isotopic techniques.

The IAEA is helping countries to implement both strategies through a variety of projects targeted at transboundary aquifers. Some focus only on the improvement of scientific understanding. Others, like the new 'Nubian Project', are working on both filling information gaps and improving inter-governmental cooperation, with financial support from the Global Environmental Facility (GEF).

Based on its experiences with transboundary aquifers, the IAEA has already achieved a number of success stories where the scientific understanding of how shared aquifers work has been enhanced. This information has further been used to help water managers better meet the needs of the populations that they serve who are dependent on groundwater resources.

For example, over the last 20 years, the IAEA conducted a wide range of studies using isotopic techniques for the Northwest Sahara Aquifer System (NWSAS), an area covering over one million sq km between the countries of Algeria, Libyan Arab Jamahariya, and Tunisia. About four million people are dependent on the system for water. In south Tunisia, it's the most important source.

Water exploitation in the NWSAS started around 1950. Today, the landscape is dotted with possibly as many as 3000 water bore holes, as use increased from 14 m^3/s in 1950 to 82 m^3/s in 2000. Current problems include declining water levels, increased pumping costs, drying up springs (e.g. Nefzaoua and Jerid regions in Tunisia) and an increased risk of water quality decline from salinization.

Gaining a Better Understanding of the NW Sahara System

Isotopic studies, in parallel with hydrogeological investigation, found that the entire system actually consists of three separate aquifer basins, in some parts superimposed on top of each other. The 'Continental Intercalaire (CI)' was found to be the biggest and deepest with some bore holes as far as 2700 m down. The 'Complexe Terminale (CT)' and 'Djefarra' aquifers reach depths of only 200 to 1000 m. These two aquifer systems are laterally the most extensive. They underlay the three countries and are

conventionally named the NWSAS. The Djefarra aquifer, shared between Tunisia and Libya, covers an area of 15 000 km^2, is a coastal littoral aquifer with major salt water intrusion problems in Libya in part because of past over-exploitation. This, in fact, forced Tripoli to get its freshwater piped up from the Nubian Aquifer System in the south through the world's biggest water transport project.

Different isotopic studies from the NWSAS show that there is a high level of inter-communication between the three aquifers, with the CI significantly recharging both the CT and Djefarra. It is now clear that some 80 % of the total recharge of the Djefarra now comes from the CI through El Hamma-Chenchou fault, in the south of Tunisia, flowing from west to east. The same situation is observed in the Amguid area in Algeria where the contribution from the CI to CT has been estimated to 65%.

This situation shows the important role played by the alimentation by ascending leakage compared with the current modern recharge which remains limited in the periphery of the domain, particularly around the Saharian Atlas, the Dahar Mountains, Tademaït and Tinrhert plateaus.

Regarding the Djefarra aquifer, a preliminary assessment of modern recharge contribution to Djeffara groundwater resources has been carried out using the isotopic mass balance. Proportions have been calculated for Tunisian and Libyan part of the basin. The mean proportion of modern water in the Tunisian part of the basin is less than in the Libyan part where it ranges around 70%.

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Coordination Meeting for IAEA Northwest Sahara Project, November 2006

The current RAF8035 project aims to gather essential and updated information on groundwater geochemical and isotopic characteristics that would be usable by water managers of the three involved countries to develop or refine appropriate models. This should facilitate the implementation of a transboundary integrated management of the shared resources. Indeed, the fourth co-ordination meeting and technical workshop held in Algiers from 11–15 November 2006 with the presence of the representatives of Algeria, Libyan Arab Jamahariya, and Tunisia, has permitted to review the data and to compile in a single common database. The data gathered so far represented approximately 900 water samples.

The samples were collected from the different aquifers, all subject of intensive exploitation for agricultural practices and other use: a) from Continental Intercalaire and equivalent aquifers; b) from the Complexe Terminale and equivalent aquifers; c) from Djeffara; and d) from the shallow unconfined aquifers and the remaining from springs and reservoirs. The samples were collected from several study sites. These include (i) the Saoura valley, the Occidental Erg, the Southern foothills of Atlas Mountains, the Tidikelt region and the Ghadames in Algeria; (ii) the Jefara plain, Jabel Nafusa area and Ghadames area in Libya; and (iii) the Dahar mountains, the Djerid area, the Nefzaoua, and the extreme South and the Djeffara plain in Tunisia. Ghadames is the region straddling the boundary of the three countries.

IAEA International Atomic Energy Agency

Water and Environment News
No. 22

May 2007

The Water and Environment News are prepared twice per year by the Isotope Hydrology Section, Division of Physical and Chemical Sciences, Department of Nuclear Sciences and Applications.

International Atomic Energy Agency
Wagramer Strasse 5, P.O. Box 100,
A-1400 Wien, Austria

Printed by the IAEA in Austria,
May 2007

07-18001