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## From the Section Head — Increasing water availability in water scarce areas



The theme of this newsletter continues our focus on the new post 2015 Sustainable Development Goals by highlighting science, technology and innovation — the thrust of SDG17 — as the engine for 21st century national development. We report our most recent and continuing efforts to adapt, innovate, expand and simplify the use of isotopes in water resource management. Coming in early 2018 these highlights look back on achievements and forward to strategic objectives and management aimed at ensuring progress toward common goals and targets such as SDG6 ‘Water for All’. Some achievements reflect increasing capabilities of national partner laboratories and counterparts to provide training, analytical and expert

services to less advanced institutions — such as Uganda’s leadership in catchment management. Other achievements reflect significant performance: results of the regional IWAVE project in Latin America; the first characterization of groundwater in the Sahel region in Africa; testing the new water balance model — IWBMiso; strengthening African technical capacities and leadership to use noble gas isotopes for groundwater age dating. Our achievements also reflect successful progress in technical innovation through research initiatives such as improving water quality by monitoring nitrogen cycling, and CRPs designed to produce guidelines for better hydrogeological characterisation of groundwater systems in the vicinity of nuclear power plants intended to improve knowledge about the behaviour for water circulation in and around NPPs and thereby improve feasibility studies, facility design, performance and safety assessment. But innovative is at the heart of our work as expressed in concepts such as isotope monitoring for variations in precipitation and potential confirmation of the Brewer-Dobson circulation model to help understand climate change.

Strategic management of the Water Resource Programme drives efforts to create the enabling environment for achieving SDG6 ‘Water for All’, including:

- Promoting confidence between water technologists and decision makers – through symposia, outreach and national consultations under IWAVE.
- Fostering collaboration between national water authorities on shared water resources – through implementation of Technical Co-operation Projects RAF7011 and RLA7018.
- Innovating tools to increase availability of groundwater and thereby reduce water scarcity – by expanding normative use of noble gases and tritium.
- Strengthening technology management by developing the analytical framework for effective use of isotopes in water resource assessments – by expanding the IAEA-Water Availability Enhancement Project – IWAVE.

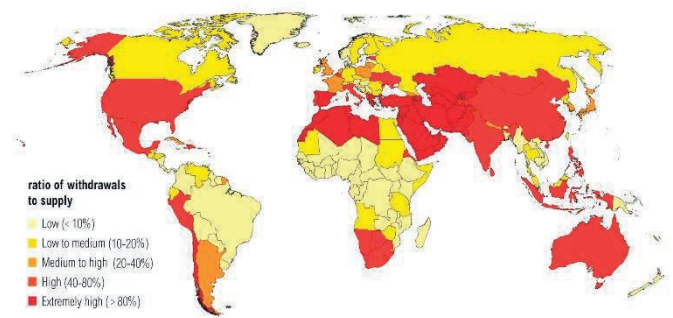
The great global challenge for the water community in the 21st century is dealing with water scarcity and stress that is predicted to affect increasing numbers of Member States as the combined impacts of population increase and climate change are fully realized. The IAEA Water Resource Programme is working closely with Member States water authorities and partners in the international water community to utilize the power of isotopes to create new and expanded knowledge about biogeochemical cycles<sup>1</sup>, and management of shared resources.

This challenge is very real. A new report, from the International Resource Panel (IRP), entitled Policy Options for Decoupling Economic Growth from Water Use and Water Pollution, envisages a dramatic increase in future demand for water predicting that almost half of the world’s population will suffer from water stress by 2030 — a mere 12 years away. The most affected region during this timeframe will be sub-Saharan Africa which could see water demand rise by almost 300% against 2005 levels. (See related story — First



<sup>1</sup> (carbon, nitrogen, phosphorus cycles and water cycles)

Water Stress by Country: 2040



NOTE: Projections are based on a business-as-usual scenario using SSP2 and RCP8.5.

For more: [ow.ly/RWop](http://ow.ly/RWop)

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overview of groundwater characteristics in the Sahel Region)

According to the report, the most cost-effective way of achieving water ‘decoupling’ — in effect, balancing water withdrawal and renewal — is for governments to create holistic water management plans that take into account the entire water cycle: from source to distribution, economic use, treatment, recycling, reuse and return to the environment.

Comprehensive water resource assessment is a critical capacity for countries facing increased water scarcity and a key technical requirement for understanding the dynamics of water scarcity is the use of isotopes - providing essential data for assessing recharge rates and mechanisms, water quality issues, as well as residence time of water in aquifers. In 2012, 65 percent of the 130 countries that responded to a UN survey on integrated water resources management reported that plans were in place at the national level, but accurate data reflecting water resource assessments was not available. It is not unrealistic to assume that less than half of these countries possess the capacity to undertake



By 2025, 1.9 billion people will live in regions with absolute water scarcity.

such assessments and thereby fully understand the changing status of their water resources.

Water use and scarcity are reflected in the SDG6 structure under target SDG 6.4 “By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity”. Member States seeking to reach this goal will require the tools, innovation and knowledge necessary to understand the causes of water scarcity and visualize the options for solution.

The management approach for increasing water availability in water stressed regions enters its second phase this year with TC projects RLA7024 and RLA7018 that demonstrate our commitment to strengthening Member States capabilities to undertake comprehensive water resource assessment. Both projects follow the IWAVE methodology designed to strengthen knowledge management about national water resource by implementing a step-wise analytical framework to understand the circumstances affecting national water resource management, identify gaps that stand in the way of national water resource goals, and organize the necessary inputs and activities to achieve national water resource objectives — particularly enabling the contribution of isotopes to national hydrological understanding. This second phase will also emphasize graduation from data, to information, to knowledge in both methodology and outcomes. We have come to realize that successful implementation of the IWAVE framework is a prerequisite for effective and routine use of isotopes and provides a management framework for comprehensive water resource assessment that can lead to increased water availability in an increasingly water stressed world.

*P. Aggarwal, Section Head,  
R. Kastens*



*You have to know where to look to increase supply when water is scarce — Sub-Saharan Africa could see water demand rise by almost 300% in the next 12 years*

## Reducing uncertainty in climate and weather modelling

### Isotope data can improve prediction of extreme weather events

Extreme weather events are becoming increasingly commonplace. Recent weather occurrences such as life threatening floods and deadly heat waves have intensified public concern about the role of global warming in driving extreme weather. New analysis shows that approximately 21 million people worldwide are affected by river floods on average each year, with that number rising to 54 million in 2030 due to climate change and socio-economic development. These concerns have sparked new initiatives to better understand and predict such events and manage their consequences.

It is scientifically well established that as the earth’s climate has warmed, extreme weather has become more frequent and severe. It is also widely accepted that all weather events in all regions are greatly influenced by the dynamics of climate change because weather is evolving in a different environment now compared to the past. Climate change is altering conditions and natural patterns and making certain types of extreme weather more frequent and more intense, and our planning, technical tools and capabilities must respond to these new challenges.

Global warming over the last century produced heat extremes that previously only occurred once every 1000 years but are now happening four to five times



*Understanding the likelihood of high intensity convective rain is essential for early warning of extreme weather.*



*In the town of Triftern, Germany on 2 June 2016, rivers and streams burst their banks with floodwaters dragging along cars, trees and possessions from flooded homes. Two women were swept to their deaths by torrential flooding in Triftern.*

more often, according to a study published in Nature Climate Change. This study found that one in five extreme rain events experienced globally are a result of the 0.85°C global rise in temperature since the Industrial Revolution, as power plants, factories and cars continue to pump out greenhouse gas emissions. Further, the intensity of extreme precipitation is expected to increase by approximately 7% per 1°C of warming. This is because atmospheric warming increases the amount of moisture in the atmosphere, causing heavier rainfall events. Changing atmospheric circulation dynamics are also shown to either amplify or weaken regional extreme weather, contributing to uncertainty in future precipitation and emergency response capabilities.



*Convective rain, a high-intensity 'thunderstorm', is characterized by higher isotope ratios and tritium levels making it possible to differentiate from lower intensity stratiform rain*

Differentiating between high and low intensity precipitation is important for providing early warning for those living at risk of life and property. Tropical and mid-latitude precipitation is fundamentally of two types, spatially-limited and high-intensity convective or widespread and lower-intensity stratiform, due to differences in vertical air motions and processes by which rain forms. These processes are difficult to

observe or model and radar observations cannot always be accurately partitioned into regions of convective and stratiform precipitation, which occasionally leads to a third 'transition' classification that increases uncertainty in forecasting. Furthermore, precipitation partitioning is also critical for understanding how the water cycle responds to climate changes. The latest climate models do not project spatially uniform increases, but rather show large uncertainties in the regional patterns of change, hampering the development of efficient adaptation strategies. Thus, finding a means to accurately partition participation is an urgent priority.

Isotopic measurements since the early 1950s have shown that stable isotope ratios are different in precipitation from different clouds, such as convective showers and frontal rains. While this has successfully explained some isotopic trends, variations during individual storms or across different regions cannot be accounted for and a comprehensive understanding of precipitation isotope variability is yet to be established. The isotopic composition of precipitation is closely related to atmospheric circulation patterns through their effects on the sources, transport paths and condensation processes across oceans and continents. Understanding the main factors controlling the isotopic content of precipitation is required for a more effective use of isotope tools in hydrology and atmospheric sciences. Relating isotope records to dynamical climate models and synoptic features of the atmospheric circulation is a powerful approach for reconstructing past climates. However, such analyses require understanding of the modern isotopic expression of climate models by investigating the temporal variation of the isotopic composition in precipitation, in order to support robust interpretations of isotopic archive data.

These boundaries are changing with the development of new isotope tools for forecasters that promise improved modelling and predictive capabilities to better manage the risk of flooding and extreme weather events by quantifying the processes responsible for storm variability, thereby reducing the uncertainty surrounding global warming impacts on extreme rain events. A new approach was introduced by the IAEA Water Resources Programme using two independent data sets — convective and stratiform precipitation fractions, derived from the Tropical Rainfall Measuring Mission satellite or synoptic cloud observations along with stable isotope and tritium compositions of surface precipitation derived from Global Network for Isotope Precipitation (GNIP). With data from 28 tropical and

two mid-latitude locations, it is shown that isotope ratios reflect rain type proportions and are negatively correlated with stratiform fractions. Convective rain forms as water and ice particles are lifted in strong updrafts. Condensation and riming (coating of tiny, white, granular ice particles) produces higher isotope ratios, along with higher tritium when riming in deep convection occurs with entrained air at higher altitudes. Stratiform rain, on the other hand, forms with ice particles growing as they fall slowly in very weak upward air motions and grow by vapour diffusion. These particles melt in an approximately 500 m thick layer before falling as relatively small rain drops compared to convective rain. Because of the significant differences in isotope ratios and tritium levels it is now possible to more accurately partition convective and stratiform fractions in weather modelling and thereby help improve prediction of the occurrence and duration of these events.

These initial results, reported in *Nature Geoscience*, show that stable isotope ratios can be used to monitor changes in precipitation – convection or stratiform – and provide an important new method to improve our ability to forecast the occurrence of violent weather events, prepare early warning and organize emergency response. More recently, improved data – much higher hourly frequency- provides data showing how isotopes change during a storm event and what those changes

mean for modelling. The IAEA Water Resources Programme is working closely with US and European partners to develop and improve applications of isotope data in climate and weather modelling that will improve certainty for climate modelling and weather forecasting. It will continue supporting this effort by providing a systematic collection of basic spatial data on the isotope content of precipitation across various temporal and spatial scales, representing a valuable contribution to the GNIP. A new CRP planned for 2019 continues the investigation into the relationship between the isotopic composition in precipitation and modern atmospheric circulation patterns and to integrate isotope data in the climate change models in order to assess climate change impacts.

These new understandings and methodologies will be particularly important for regions at higher risk of extreme weather, many of which lack adequate prediction and emergency response capabilities. The international community has been asked to support introduction of these tools and knowledge to help developing countries achieve Sustainable Development Goal 13 “Take urgent action to combat climate change and its impacts” and the SDG target (13.3): “Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning”.

*R. Kastens, P. Aggarwal.*



# Achievements in Africa and Latin America

## First overview of groundwater characteristics in the Sahel Region

Home to 135 million people, the Sahel stretches from West Africa to Central and North Africa, and spans over 7 million km<sup>2</sup>. One of the biggest challenges the region faces is access to clean water. Potable water is essential for people, not only for drinking, but also for food production and sanitation. For the past few decades the region has suffered from extreme drought, inflicting a severe water burden on the area, impacting agriculture and causing widespread hunger.

To help national water authorities understand the challenges and open opportunities to collaborate on joint management and technical issues, the TC Regional Project RAF7011 “Integrated and Sustainable Management of Shared Aquifer Systems and Basins of the Sahel Region”, was initiated in 2012, with support and contributions from the Republic of Korea, Sweden, Japan, New Zealand, and the USA through the Peaceful Uses Initiative, and including in-kind contributions from Australia. With a budget of €2 249 222, the overall project objective was to enable rational and sustainable management of shared groundwater resources in the Sahel region to support sustainable socioeconomic development. The project covered five major trans-boundary aquifer systems — the Iullemeden Aquifer System, the Liptako-Gourma-Upper Volta System, the Senegalo-Mauritanian Basin, the Lake Chad Basin and the Taoudeni Basin — that are shared by thirteen African Member States: Algeria, Benin, Burkina Faso, Cameroon, Central African

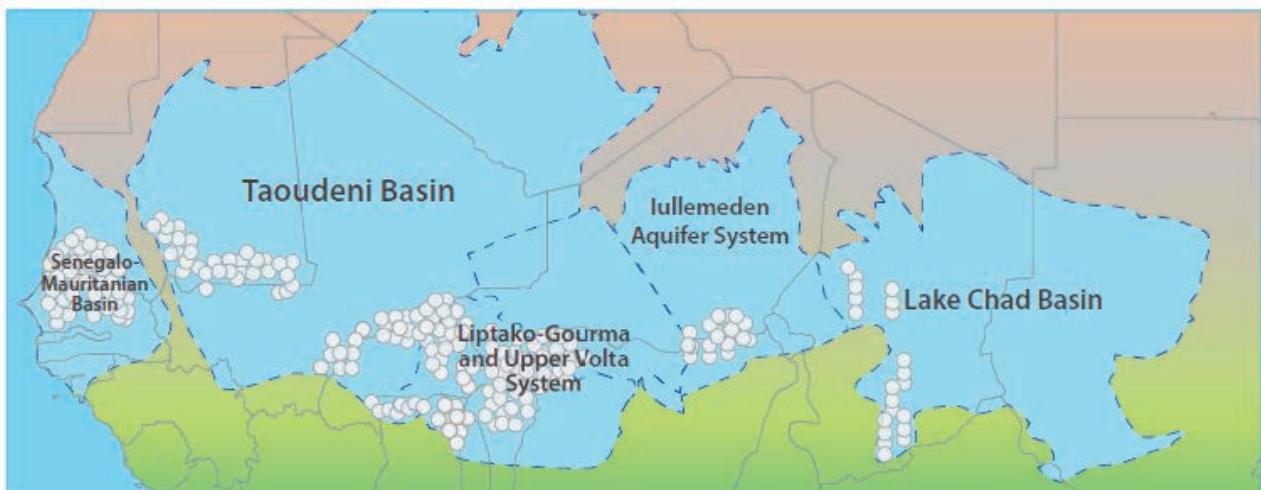


*Water sampling campaigns were undertaken in all five basins.*

Republic, Chad, Ghana, Mali, Mauritania, Niger, Nigeria, Senegal and Togo.

Project activities were successfully concluded in 2017 with several ‘firsts’, and most importantly gaining the experience of effective collaboration on technical and management issues at both the basin and sub-regional levels. The major results included:

- The first broad overview of groundwater characteristics in the Sahel Region.
- Developed human and technical capacities in thirteen participating countries leading to water sampling and monitoring campaigns that will sustain and improve management of the aquifers.
- Made available data for evidence basis policy and decision making to better manage the shared water resource in Sahel region.
- Established the source of the groundwater recharge for the first time — essential for protecting the groundwater, such as in the Lake Chad Basin, against pollution.



Location of the five aquifer basins and systems studied in the Sahel. The dots show where scientists collected water samples.

Image: IAEA

- Discovered large quantities of good quality groundwater, suitable for human consumption, in several parts of the project area.
- Confirmed that areas where groundwater has become contaminated appear to be isolated at present.
- Established the interconnectedness of various water aquifers and the relationship between surface water and groundwater in the Iullemeden Aquifer System, the Lake Chad Basin, and the Liptako-Gourma aquifer system.
- Presented major new findings on recharge and flow patterns in the Maastrichtian aquifer, the Senegal River, and the southern boundary of the Lake Chad basin.

Another first will be the publication of a comprehensive groundwater characterization map covering all five basins studied in the Project. This is expected to be published in the Hydrogeology Journal in summer 2018, and will be covered in a future Newsletter.

A follow-up project (RAF7019) incorporating the IAEA Water Availability Enhancement methodology (IWAVE) has been designed building on the achievements of RAF7011 and aiming to further integrate management of groundwater resources in the Sahel countries by operationalizing the network of counterpart institutions to complete the characterization, management and monitoring of groundwater resources and by translating hydrological data into policies and legal frameworks. The IWAVE component of the project will be led by Benin, Cameroon, Ghana, Niger and Nigeria lending special focus on promoting good water governance – building confidence in the quality of data and interpretation as a foundation for water law, regulation and policy. One approach planned is to promote outreach materials based on data interpretation – for non-technical audiences – explaining groundwater dynamics in terms of risk management options. These 5 countries met in February 2018 to prepare their national IWAVE work plans and expected outputs. The technical and management capabilities resulting from this second phase Sahel project are expected to provide core leadership and expertise for the management of shared water resources in Africa and contribute to African Member States achievement of their SDG6 plans and targets.

*R. Kastens, L. Araguas*



*For about 100 million people in Sub Sahara Africa groundwater is the only source for domestic use, agriculture and livestock rearing.*

## Latin America links hydrological data to decision making in support of SDG 6: Clean Water and Sanitation

Latin America is home to one-third of the world's freshwater resources, but the region also includes large arid and semi-arid areas from Mexico to the high Andes with recurring droughts. Water scarcity is expected to increase in several areas due to climate change, particularly in the Andes where melting glaciers will also affect water supply systems. While these consequences are speculative it is widely agreed that changes in water supply will have the most dramatic effect on the region.

Furthermore, access to water is still highly unequal due primarily to rapid urbanization in the region that skewed water services towards the urban populations and left many rural communities - some 30 million Latin Americans — without access to safe drinking water. Moreover, many aquifers are vulnerable to pollution as only 20% of waste water in Latin America is treated, leading to pollution of rivers and coastal areas, which not only exposes the resident population to pollutants and disease but has tremendous environmental impacts. The convergence of these effects present major challenges to water supply systems and their management.

Groundwater resources in many parts of Latin America are the main and sometimes only source of water, providing services for urban supply, development and economic activities and maintenance of ecosystems, among others. Sustainable management of groundwater is greatly influenced by the technical, operational and



*Groundwater sampling for chemical and isotope analyses in Colombia.*

management capabilities of national institutions and the level of collaboration on transboundary water issues.

Efforts to solve these problems have largely been ineffective or inadequate due to deficiencies in comprehensive understanding of basic and advanced hydrology at the basin and catchment levels.

These problems are not unique to Latin America as recognized in the post 2015 Sustainable Development Goals adopted by the United Nations General Assembly. They include a unifying goal for water resources management: SDG 6 "Ensure availability and sustainable management of water and sanitation for all". For the achievement of this goal by 2030, it will be necessary to increase availability and water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater. The recommended solution is to implement integrated water resources management at all levels, and to expand international cooperation and technical scientific capacity to realize the 'Water for All' goal.

The IAEA developed the Water Availability Enhancement Project (IWAVE) to enable Member States to increase the availability and sustainability of freshwater and thereby achieve their SDG6 targets. The IWAVE aims to enable comprehensive assessments of national water resources through step-wise methodology that: identifies national gaps in hydrological data and information; determines the expertise, technology and infrastructure support required to fill identified gaps; formulates and implements the optimum methodology for utilizing isotope techniques and develops strategies for

collaborating with other multilateral and bilateral organizations to fill identified gaps.

In Latin America, RLA7018 "Improving knowledge of groundwater resources to contribute to its protection, integrated management and governance" is concluding its activities, one of which was to introduce the IWAVE methodology to improve the availability, quality and governance of water resources in the region. Eleven Latin American countries evaluated the availability of hydrological information, legal regulations, public policies and social and technical aspects, identified technical and data gaps, and strengthened necessary capacities through regional or national training courses and fellowships. Four pilot countries, Argentina, Brazil, Ecuador and Nicaragua prepared action plans that reflected the identification and filling of gaps in hydrological knowledge and institutional capabilities. The application of IWAVE methodology, requiring strong synergies among the different institutions involved in the management, research and supply of water resources, brought a structured analytical and feasibility phase into water resource management lending a sharper focus on human resource requirements and key national capacities. It also provided the prerequisite technical basis for successful applications of isotope data for integrated water resource management. This framework will guide countries to become more efficient and effective meeting the different and specific problems and challenges related to sustainable water resources and adaptation to climate change.

Overall, RLA7018 produced isotope data and analysis that contributed to the hydrochemical and hydrogeological understanding and characterization of ground waters enabling identification of recharge areas, evaporation processes, and dating of waters (using oxygen-18 and hydrogen-2, hydrogen-3, helium-3 and carbon-14). Special attention focused on human resources development through hands-on fellowships, national and regional training workshops and courses, and acquisition of specialized equipment.

RLA7018 was also successful in promoting management cooperation and technical collaboration between project counterparts in the Latin American region through exchange of information about common problems and constraints, and by sharing the state of knowledge on solutions and management strategies. IAEA's guiding principle is to promote cooperation 'between' regional project counterparts and enable it through technical and logistical assistance during implementation of the project fostering strong





*Training course on “Hydrogeological Mapping for Professionals of National and Regional Water Institutions”, held in Ecuador in 2017.*

ownership and self-reliance. Mechanisms for South–South Cooperation were formalized through bilateral relationships, for example with experts from Argentina and Colombia leading courses, workshops and consultations in Ecuador and Nicaragua. In Argentina, the Universidad Mar del Plata laboratory analyzed the isotopic compositions of water samples from different counterparts of the region. Ibero-American cooperation played an important role in the Project whereby experts from Spain and Portugal provided their expertise in scientific, technological and water resource management issues, with Spain also providing extra budgetary contributions.

Implementation of the Isotope Hydrology Laboratory in Nicaragua with the technical advice of an Argentine expert, as part of the South–South Cooperation, was also developed in the framework of the project.

The specific outcomes of the project included increased awareness by decision-makers of the importance of hydrological knowledge to improve water resources performance and management. Several high-level officials from water management agencies recognized gaps in hydrological understanding, including poor knowledge of water use and deficiencies in water resource planning and management due to institutional weaknesses, poor implementation of integrated water resource management and the lack of predictive models involving global change. These findings played an important role in guiding the content of knowledge to be acquired and defining the technical and institutional capacities to be strengthened as part of strategic water management in their respective countries.

Some of the major outputs include:

- Current and planned land use maps helped develop predictive models of global climate change in order

to propose more appropriate adaptation and mitigation actions.

- New hydrological national databases established enabling data source integration, and interpretation of data in a new framework for a social and economic development of participating member states.
- The development and implementation of the National Water Agendas that have identified the actions and processes that must be tackled by the water sector and civil society in terms of protection of water resources.
- The establishment of regional isotope monitoring networks and the use of isotopic tools to characterize recharge processes, identify the origin of pollution and age of groundwater, and the development / improvement of hydrogeological conceptual models that will benefit the region’s progress towards sustainable water resources.

The methodology, successfully followed in the IWAVE Pilot countries, will be expanded through a follow-up project in the region. The new project — RLA7024 — continues the focus on expanding technical capacity to conduct comprehensive assessments of water resources in support of the Sustainable Development Goals (SDG 6), increasing water availability by promoting the use of isotope hydrology in Latin America.

*E. Bocanegra, Universidad Mar del Plata, Argentina  
R. Kastens, L. Ortega.*

## Uganda demonstrates leadership in Catchment Management

Beginning in 2011, the Ugandan Directorate of Water Resources Management of the Ministry of Water and Environment embarked on an ambitious programme to decentralize responsibility and manage water resource at the catchment–basin level by creating Water Management Zones (WMZ). With the financial support from Danish DANIDA, German GIZ and the Austrian Development Agency, by 2014 four WMZs were created in Kyoga with a Eastern Region office in Mbale; Upper Nile with a Northern Region office in Lira; Victoria with a South Western Region office in Mbarara, and; Albert with a Western Region office in Fort Portal, Kabarole. The WMZ structure includes



*Uganda's four WMZs and eight major catchments*

stakeholder fora, management and technical committees and dedicated secretariat, and it is at this level that Uganda's integrated water resource management planning takes place — responding to SDG6.5. SDG6 is under the direct supervision of Minister of State for Water, Hon. Ronald Kibuule, and this high-level leadership has brought operational and political support to the pursuit of the 'Water for All' goal in Uganda. The WMZs have 3 objectives: improved water quality; improved water quantity and better livelihood opportunities. Recently, the DWRM initiated activities to expand management into new catchments areas and requested the IAEA WRP to collaborate in planning and design of Katonga Catchment Management Plan and Water Resources Protection Guidelines.

Within the Western WMZ, the Katonga River Basin is an important source of water for approximately 2.1 million mostly rural population located in the southwestern part of Uganda. Its 220 km channel is continuous between Lake Victoria and Lake George, reflecting that it once drained away from Lake Victoria into Lake George along its entire length. Regional uplifting events associated with the geologically active East African Rift has caused a shift in the watershed for the Katonga River, which now principally flows east into Lake Victoria.

The first step was to organize a workshop with the principle actors to define requirements and prepare implementation plans for Catchment Management Plan and Water Resources Protection Guidelines that took place 14–18 August 2017. The key activities to be incorporated in the plan included:

- Mapping and understanding the different sources of water in a catchment and the application of isotope hydrology to aid in differentiating the role groundwater plays at catchment level (surface water groundwater interaction).
- Delineation and characterization of water sources through isotope hydrology at catchment level should inform water source protection (extent).
- Integration of the IAEA water balance model (iWBMIso) being developed at catchment level into the Water Information System (WIS) under development by DWRM with support of the World Bank.

Implementation of the agreed plan began almost immediately with expert support to initiate sampling campaign in the Katonga catchment. The sampling strategy will extend beyond the catchment boundaries to provide a preliminary indication of the water resources situation outside Katonga catchment, and follow an approach with samples collected from the whole catchment in representation of all geologic units, valley beds and slopes for use in establishing baseline situation. The selection of the sampling locations and frequency, field data collection templates and procedures have been completed as has a baseline hydrochemistry database using the GNIP stations.

This emphasis on generation of baseline information is an important development as it provides key information for identifying areas where isotope techniques can be applied for example (i) policy formulation for groundwater development (sustainable exploitation now and in future where is it necessary and how to carry out artificial recharge), (ii) understanding trans-boundary groundwater interactions, (iii)



*Water in Uganda is reasonably abundant but climate change and population increase means resources need to be safeguarded and sustainably used.*

identifying impacts of mining activities with groundwater (iv) land use/land cover, aquifer stratigraphy, groundwater pollution management (v) source protection.

Strengthening capacity in certain areas, such as data interpretation and upgrading laboratory capability are also important elements of the plan, some of which will be undertaken through future technical cooperation projects. The new prototype TEU will be constructed for installation and DWRM will be one of the first African laboratory capable of measuring tritium. In preparation, human resource requirements were identified and training initiated during the workshop on the new iWBM. A water balance model (see News in Brief). Another feasibility activity considered important was the introduction of the IWAVE methodology, given the WMZ structure and lead role in groundwater management assigned to DWRM. This will be important for identifying gaps between national water resource plans and objectives and the necessary technical capabilities to provide the required data for informed decision making. It also provides a 'blue print' for future HR development in DWRM.

Uganda's national commitment to catchment management and organizational structures along with the technical capability and vision of DWRM provide a model and resource for other African countries facing water scarcity and conservation challenges. The Water Resource Programme foresees an expanding role for DWRM providing analytical services and expertise to the sub-region and in support of transboundary initiatives such as RAF7019 (see related story) as it expands its capabilities and leadership in water management.

*R. Kastens*

## The IAEA Collaborating Centres: promoting leadership and cooperation

The IAEA Collaborating Centres Scheme provides the Agency with a mechanism to designate eligible Member State institutions as partners that assist in implementing its programmatic activities, taking into account the Member State's expanding scientific and technical capabilities. The Collaborating Centres Scheme was initiated by the Department of Nuclear Sciences and Applications on a three-year pilot basis in

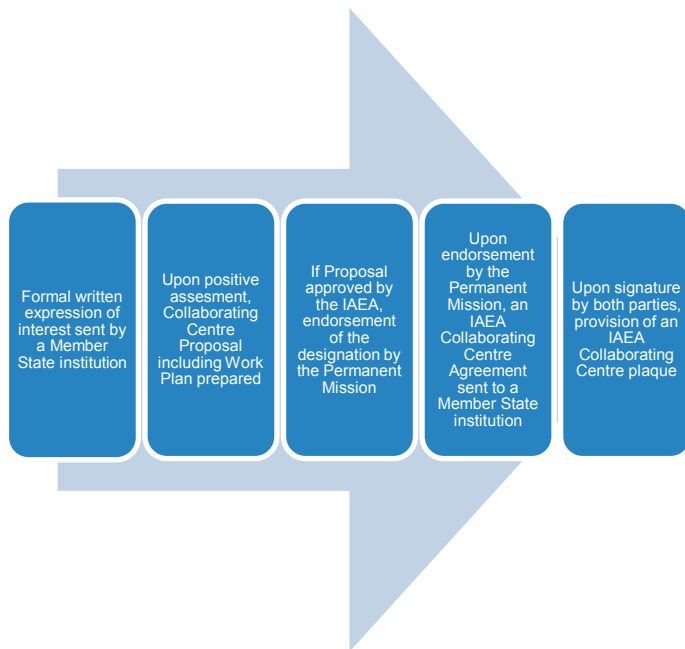


*Sustainable management and protection are key conditions for ensuring future generations have ready access to good quality water resources.*

2004. Upon completion of the pilot phase in 2008, and approval by the Director General the Scheme became fully operational and open to all interested Member State institutions. Collaborating Centres support the IAEA's programmatic activities through the implementation of a Work Plan that is agreed with the relevant Technical Division. The process begins with a formal *expression of interest* by the national institute expressed through its highest executive officer. The relevant Technical Division(s) evaluate the institution's ability, capacity, and readiness to directly contribute to specific Regular Programme projects and activities as contained in the IAEA's Programme and Budget, and selects national institutions according to specific criteria, such as: the scientific and technical standing of the institution at the national and international levels; the technical relevance of the institution to the IAEA's programmatic priorities; the interested institution's prospective stability in terms of personnel, activities, and funding; its working relationship with other national institutions as well as at the bilateral, regional and international levels; the institution's adherence to nuclear safety and security guidelines and principles, as applicable; and whether the institution's mandate, internal regulatory framework, its relationships and practices are fully compatible with the IAEA's mandate. Currently, two national institutions are designated Collaborating Centres for the WRP — the Geological Survey of Brazil (CPRM) and CNESTEN.

### CNESTEN

The National Centre for Energy, Science and Nuclear Techniques (CNESTEN) in Morocco, is a Collaborating Centre (CC) in the field of Water Resources Assessment and Management and as Regional Designated Centre for Environmental Isotope Hydrology in Africa (RDC) designated in 2015. In this



*The designation process for Collaborating Centres*

capacity it complements and supports the efforts of the Water Resource Programme and AFRA in this area. In partnership with the relevant authorities, the IAEA and other national and international partners (MDCE, DRPE, ABHs, IRD, Universities), CNESTEN has pursued projects initiated in late 2015 and early 2016, in the following areas”.

During 2015- 2016, CNESTEN undertook capacity building, training and analytical support

- Supervision of a Student from University Chouârb Doukkali of El Jadida for obtaining a Master degree in isotope hydrology.
- Supervision of a Student from University of Aix en Provence (France) for obtaining a Master degree in isotope hydrology.

In terms of laboratory capacity building and Analytical Quality Control, CNESTEN has completed the following tasks:

1. Participation in International Inter-laboratory exercises in the field of stable isotopes ( $^{18}\text{O}$ ,  $^2\text{H}$ ,  $^{13}\text{C}$ ,  $^{15}\text{N}$ ) and traces elements, organized by the IAEA through the following programs (WICO 2016; WEPAL and Eurofins Scientific (FIT).
2. Installation and commissioning of new analytical techniques for stable isotope analysis in water samples: Picarro Laser spectrometer;
3. Development of new methods of microwave digestion;

4. Implementation of a Quality Management System ‘LIMS’ for sample management and data reporting of stable isotope analyses.
5. Deployment of a new analytical technique at CNESTEN: gas chromatography coupled with mass spectrometry (GCMS).

Within this framework, the CNESTEN provided, training for 17 African fellows and performed isotope and hydrochemical analysis of about 1500 samples, and conducted 5 IAEA Expert Missions to various Member States

In terms of future activities, the Work Plan will include:

6. Start two new studies on groundwater resources in the south and north-west of Morocco, within the framework of a new Research & Development Agreement with the Ministry of Water
7. Promote the development of the National Hydrological Networks
8. Support Member States capabilities for using isotope hydrology for sustainable groundwater management
9. Continue research work with the IAEA, in collaboration with Ministry of Water and Universities, under the Coordinated Research Projects where the CNESTEN is actively involved.
10. Continue provision of support in terms of capacity building and training, expert services and analytical services to Member States within the framework of Technical Cooperation Projects and AFRA agreement.
11. Raise awareness on the usefulness of isotope hydrology applications in water resources management programs at the national and regional levels.
12. Expand use of information and communication technologies (ICT) and space technology in water resources development and management
13. Participate in IAEA analytical proficiency tests.

Scientific and technical publications relevant to CNESTEN’s Work Plan include 17 subjects such as: Remote Sensing of Water Resources in the semi-arid Mediterranean areas; Integration of geochemical and isotopic tracers for elucidating Groundwater recharge in Berrechid Basin; Evapotranspiration partitioning components in an irrigated winter wheat field; Estimating Recent Sedimentation rates using lead-210

in tropical estuarine systems; Towards global applicability—exploring the potential of the compound-specific stable isotope technique to detect hot spots of soil erosion across catchments and agro-ecologies, and other important contributions to further understanding of environmental isotopes.

Two national institutions have initiated the process for designation as a Collaborating Centres for the WRP by submitting formal expressions of interest: The Vietnam Atomic Energy Institute (VINATOM), and The Thailand Institute of Nuclear Technology (TINT). The Section Head of the IAEA’s Isotope Hydrology Section undertook a mission to TINT and VINATOM from 30 October to 3 November 2017, to assess capabilities and discuss areas of possible collaboration and the best ‘fit’ for future partnerships. The specific areas for possible collaboration will be developed over the next months, however they will likely focus on consolidating and sharing the experience of building each country’s groundwater characterization and expanding /establishing rainwater databases in new areas in South East Asia. Expanded participation in ALMERA laboratory activities for measurement of radionuclides in the environment (terrestrial and marine) for emergency preparedness is also an expectation with provision of laboratory proficiency tests and hosting training courses and coordination meetings in the sub region. The collaboration is expected to enhance research capabilities and strengthen collaboration on hydrological and environmental challenges in South East Asia. More information on the Scheme is available on line: <https://www.iaea.org/about/partnerships/collaborating-centres>

R. Kastens

## “Water, water, everywhere, Nor any drop to drink” Water tasting event

*The Rime of the Ancient Mariner* by Samuel Taylor Coleridge reminds us that while it’s a blue planet, freshwater makes up less than 3% of the total and available freshwater is half of that because 1.5% remains locked in polar ice. This was the theme of a water tasting event that took place on 25 August 2017 as part of a special Seminar for Diplomats at IAEA headquarters in Vienna Austria. The purpose of the event was to explain that most of the available



DDG-NA Aldo Malavasi explains water scarcity.



The fossil water of the Ogallala aquifer in North America is being depleted at rates that cannot be replenished.

freshwater is groundwater and much of it has not been recently replenished (also called ‘fossil water’), which describes water that has been contained in an undisturbed aquifer for millennia. Participants were offered tastings of seasonal water from the Vienna’s watershed, 39 000 year-old water from deep aquifers in Austria, and 500 000 year old water from Estonia. Participants were asked if they tasted a difference between modern and fossil water. Did it taste different, better, purer, sweeter?

The point of the exercise was to demonstrate that while there was usually no apparent difference in quality, there was a difference from the standpoint of sustainability because pumping groundwater that’s 200 000 years old means it’s not or barely recharging and exploitation is not likely to be without consequences, often altering water balances and harming surface ecosystems as well as jeopardizing investments in agricultural production and food security. It was explained that isotopes are a key tool

for understanding the age of groundwater; its age or residence time, rate of replenishment, and its pathways both between surface and ground and returning to the sea as part of the hydrological cycle — important characteristics for understanding and managing water for sustainable use.

It was also explained that fossil water could be found almost everywhere with major concentrations in every continent. In some areas, such as the Ogallala aquifer in North America, fossil water is being depleted at alarming rates that can never be replenished. A 2014 USGS study, found there was a drop of 4.7 m in the system from predevelopment times (before 1950) to 2013, with 0.65 m of that loss occurring between 2011 and 2013. That's 13.6 percent of the loss occurring in just two years, and it is now estimated that the aquifer will be 70 depleted by 2040 presenting a huge challenge for the 'Breadbasket of America'.

Lastly, the work of the Water Resource Programme to strengthen knowledge and advance technology for groundwater dating was demonstrated with a visit to the IAEA Isotope Hydrology Laboratory where visitors were introduced to the function of Noble Gas Mass Spectrometry, Laser Absorption Spectrometry and Ultra High Precision Stable Isotope-Ration Mass Spectrometry (IRMS), along with the interpretations that are derived from the measurements. They also saw the laboratory staff constructing Tritium Enrichment Units (TEU) for introduction in advanced Member State laboratories (see related article on Uganda's leadership in catchment management)

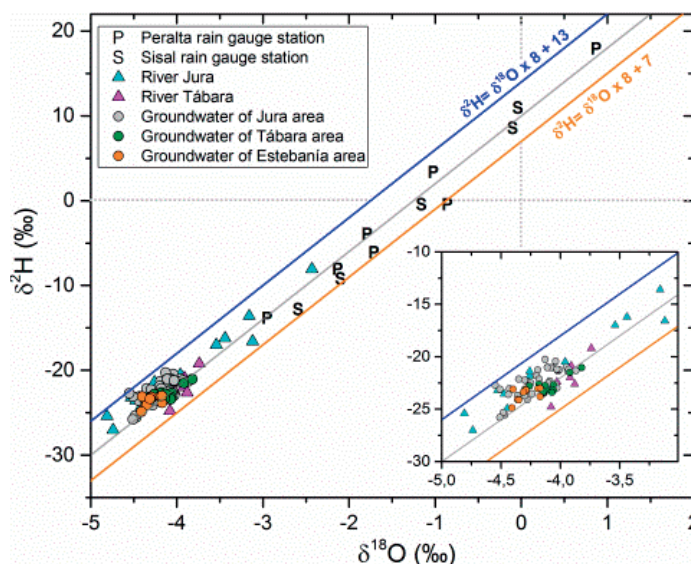
R. Kastens

## Case study on use of isotopes in Dominican Republic

Problems of groundwater pollution affect many Member States but few have the tools and expertise to understand the extent and causal relationships. With the help of an expert mission in September 2017, the National Geological Survey (SGN) was able to identify and address gaps in hydrological information and develop a conceptual hydrological model to understand processes of contamination in the alluvial aquifer of the plain of Azua, including the identification of sources of pollution, areas with increased vulnerability, processes of natural attenuation and interpreting isotopic data of nitrate functioning.



*Pollution processes in the aquifer of the plain of Azua was little understood*



*Figure 1. Stable isotopes of water from rain (Peralta and Sisal rain-gauge stations), rivers (River Jura and Tábara) and groundwater from Azua alluvial aquifer collected in the framework of the project RLA7021.*

Earlier hydro-geochemical and isotopic campaigns carried out by SGN created a database with a large spatial and temporal dimension including hydrological data from water samples collected from meteorological stations, surface streams which drain towards the plain of Azua (River Jura and Tábara) and groundwater from the aquifer. The isotopic data provided key information on the main mechanisms of groundwater recharge and helped adopting some aquifer management proposals. It came to be understood that the isotopic signal of groundwater ( $\delta^2\text{H}$  and  $\delta^{18}\text{O}$ ) from the Azua plain (Jura, Tábara and Estebanía areas: Fig. 1) did not fit and were isotopically more depleted than the average isotopic signal of rain collected in the nearby rain-gauge stations (P and S, Fig. 1). Furthermore, the mean isotopic content value of surface streams (River Jura and

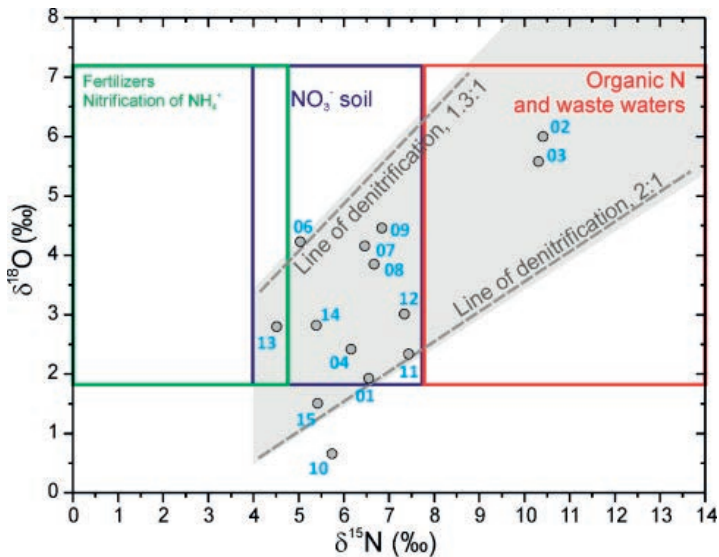


Figure 2.  $\delta^{15}\text{N}$  vs.  $\delta^{18}\text{O}$  (in permil) of nitrate for the July 2016 groundwater field sampling at Azua alluvial aquifer. Compositional boxes refer to the sources of nitrate. Isotopic contents of inorganic and organic fertilizers, nitrogen from septic tanks and soil have been extracted from the literature.  $\delta^{18}\text{O}$  values of nitrate from nitrification were calculated by the application of the equation:  $\delta^{18}\text{O}_{\text{NO}_3} = 2/3 \cdot \delta^{18}\text{O}_{\text{H}_2\text{O}} + 1/3 \cdot \delta^{18}\text{O}_{\text{O}_2}$ . The range of  $\delta^{18}\text{O}$  values of water were derived from recharge waters and groundwater of the Azua plain (-3.82 ‰ and -4.81 ‰ in Figure 1) and the most frequent value of  $\delta^{18}\text{O}$  of dissolved oxygen was +25 ‰. Denitrification lines with slopes of 2:1 and 1.3:1, according to literature, and field of denitrification (in grey) are also shown.

Tábara) is similar to those from groundwater. With this information it was possible to conclude that groundwater of the plain of Azua derives mostly from recharge of surface resources (River Jura and Tábara) through the river-aquifer interaction.

The fact that  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$  contents of river waters are more depleted than that of the Peralta rain-gauge station (elevation 500 m) suggests higher recharge elevation for the water drained by these two surface streams. By using an average gradient of  $-0.25 \text{ ‰ } \delta^{18}\text{O}/100 \text{ m}$  and



Collecting precipitation samples in the study area.

considering a value of  $-1.00 \text{ ‰}$  and  $-4.00 \text{ ‰}$  for Peralta and surface waters (Fig. 1), respectively, it is possible to infer that the runoff that feeds Tábara and Jura rivers is produced at elevations 1,200 m above the Peralta rain-gauge station (500 m) and it is precisely 1,700 m the elevation of the higher peaks of the northern mountains of Sierra de Ocoa, the headwater area of the Jura and Tábara rivers.

The plain of Azua is one of the most important agricultural areas in the Dominican Republic and, therefore, any policy related to water management must account for groundwater because it supplies an important part of water for the high-value crops produced in this plain. Any possible water regulation of those rivers will imply environmental and economic consequences due to (1) decreasing volume of recharge, (2) active sea-water intrusion, and (3) neutralizing the dilution effect of the high-quality water of Tábara and Jura rivers (electrical conductivity:  $304 \mu\text{S}/\text{cm}$ ,  $\text{NO}_3^-$ :  $3.6 \text{ mg}/\text{L}$  and  $\text{SO}_4^{2-}$ :  $9.0 \text{ mg}/\text{L}$ ) as they mix with groundwater.

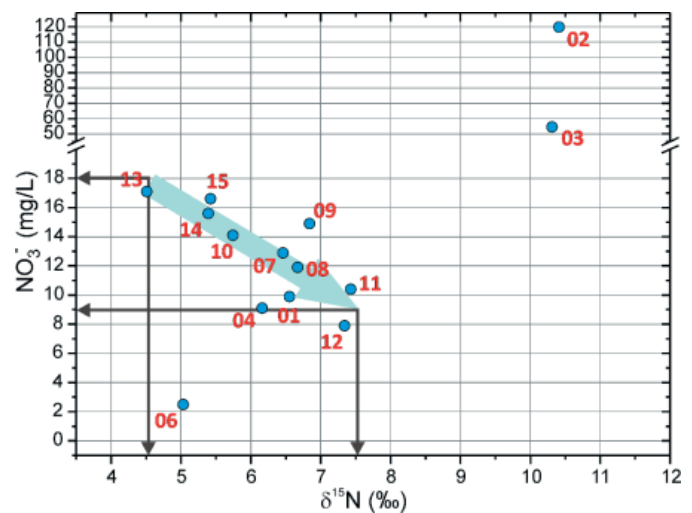


Figure 3.  $\delta^{15}\text{N}$  vs.  $\text{NO}_3^-$  for the July 2016 field sampling campaign at Azua alluvial aquifer. It is observed an inverse correlation (blue arrow) between both parameters indicating a heavier  $\delta^{15}\text{N}$  with a lower concentration of nitrate.

In order to determine groundwater contamination status and potential pollution sources, a sampling campaign using  $\delta^{15}\text{N}$  and  $\delta^{18}\text{O}$  was conducted in July 2016 (Figure 2). Through these results it was possible to identify sources of nitrate and possible reactions through the analysis of stable nitrate isotopes ( $\delta^{15}\text{N}$  and  $\delta^{18}\text{O}$ ). The study has established a conceptual model for the contamination of the aquifer, identification of pollution sources and processes of natural attenuation by interpreting isotopic data of nitrate.



*A sampling campaign carried out in July 2016 identified sources of nitrate and possible reactions through the analysis of stable nitrate isotopes ( $\delta^{15}N$  and  $\delta^{18}O$ ) that later was established as a network of monitoring points. The study has developed a conceptual model of groundwater contamination, identification of pollution sources and processes of natural attenuation by interpreting isotopic data of nitrate ( $\delta^{15}N$  and  $\delta^{18}O$ ).*

In addition to fertilizers as nitrogen sources, organic nitrogen from urban wastewaters was also been detected. Two of the samples (No. 02 and 03) are plotted in the compositional box of “Organic and waste waters” (Figure 2). Those waters were collected in two wells in the middle of urban areas in Estebanía plain, so it is likely representing urban contamination by leakage of urban waste waters through the pipeline system. Support to sources is the high concentration of nitrate (Figure 3) and chloride of both points (100 mg/L and 65 mg/L, respectively).

Another important result of the study was the evidence of denitrification processes of the nitrate molecule. During these reactions ( $NO_3^- \rightarrow N_2$ ), denitrifying bacteria use preferably  $^{14}N$  and  $^{16}O$  instead of  $^{15}N$  and  $^{18}O$  to metabolize the nitrate molecule, and therefore,  $\delta^{15}N$  and  $\delta^{18}O$  contents of the unreacted nitrate increase as nitrate concentrations decrease. This relation is observed in groundwater samples of the Azua plain (Figure 3) and also it is possible to identify in Figure 2, where all samples (with the exception of points 02 and 03) follow an increasing tendency in the  $\delta^{15}N$  and  $\delta^{18}O$  contents, in good agreement with the theoretical denitrification lines. Therefore, there is a sink of nitrate in this aquifer following this redox reaction.

The study also confirmed key new findings for future action:

- A conceptual model of aquifer contamination has been established through the combined use of isotopic data ( $\delta^{15}N$  and  $\delta^{18}O$ ) and hydrochemistry, including the origin of the nitrogen compounds (ammonium fertilizers and organic nitrogen from urban wastewaters) and the prominent geochemical

processes: volatilization, nitrification and denitrification.

- Being that groundwater the main source of water supply to the population, it is important to continue and expand the existing monitoring network to detect possible increases in certain compounds of agricultural origin, including pesticides. Further, there is a need to strengthen national capabilities to carry out hydrochemical and isotopic analyses of water.
- Isotopic data have provided strong evidence that the main recharge source for the Azua aquifer system is the infiltration of surface water from rivers in the upper part of the water basin. Additional work should be undertaken to fully evaluate recharge processes, both in terms of quantity and quality, through the shallow water courses that reach the plain of Azua, in particular, the flow rates of the water inlets of the water canals. In this context, it is necessary to fully account for the effects of groundwater recharge from irrigation return. Any further development in terms of dam construction will decrease the groundwater volume available for irrigation and probably may influence the salt/fresh water interface.

*Iñaki Vadillo, University of Malaga, Spain.  
R. Kastens*

## News in Brief

### New CRPs for 2018

In December 2017, the CRAA formally approved four new CRPs proposed by the Water Resource Programme. This body of work presents a strategic approach to applied research aimed at innovating tools, broadening experience and creating new knowledge to help Member States overcome the challenges of water scarcity and conservation. The purpose and objective of each CPR is explained below. Each CRP presumes that:

- Interested counterpart institutes are currently engaged in related technical areas.
- Appropriate staffing is available for field and analytical work; laboratory premises and computing facilities are available at participating institutes to conduct isotopic and chemical analysis.



- National authorities/institutes will provide all necessary permissions and support in a timely manner.
- There is on-going research or interested and competent professionals in the areas of investigation — hydrology, isotope analysis, water pollution, etc.

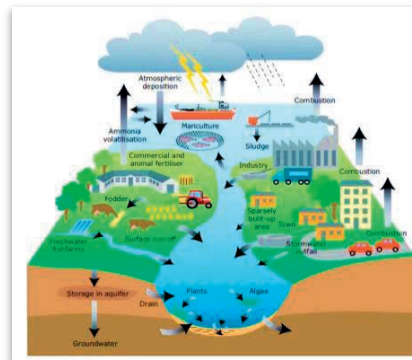
For more information on submission procedure please visit IAEA CRP website <https://cra.iaea.org/cra/index.html>

### CRP F32008: Global Monitoring of Nitrogen Isotopes in Atmospheric Waters

Nutrient pollution is one of the most widespread, costly and challenging environmental problems facing developing and developed countries. It is caused by excess nitrogen in the air and water and occurs when nitrogen deposition exceeds the remediation capacity or critical load of the aquatic system. Nitrogen is essential for the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water. But when too much nitrogen enters the environment — usually from a wide range of human activities — the air and water can become polluted. Nutrient pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, along with impact on economies. Human activities have doubled the amount of reactive nitrogen in the atmosphere over pre-industrial times and have had major impact on ground water - which billions of people use as their drinking water source – becoming harmful, even at low levels.

The IAEA's Water Resource Programme is continuing research (begun under F32007: Isotopes to study nitrogen pollution and eutrophication of rivers and lakes — see Environment & Environment Newsletter No 33 Sept 2016) aimed at understanding how N pollutants are introduced in the terrestrial aquatic environments via wet deposition in order to define the contribution of atmospheric nitrogen in the degradation of water resources. Wet deposition occurs when nitrogen compounds in the atmosphere are transported to the earth's surface after their inclusion or solution in precipitation (rain, fog and snow). The new CPF resulted from an expert meeting on current practices related to the release of nitrogen compounds in the atmosphere and their impact in the terrestrial environment and aquatic systems through wet deposition and provides input on the current status in terms of analytics, gaps and findings and recommends

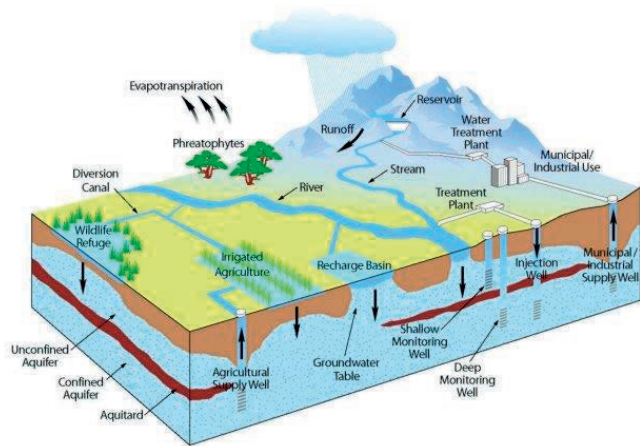
The increasing production of food and energy worldwide has multiplied today's anthropogenic emissions of nitrogen compounds in the atmosphere, which are transported and deposited through precipitation on the terrestrial and aquatic systems. Disruption of N-balance, eutrophication in rivers and lakes, and stream acidification are a few of the negative consequences, when N-deposition exceeds the remediation capacity or critical load of the aquatic system



how N-isotopes can be part of this effort. This included how to improve data quality and expand the monitoring networks to areas not adequately covered, especially in Asia and Africa. The outcome of this technical meeting led to the preparation of the CRP proposal F32008 which was approved in December 2017.

The expected results of the CRP will be that N-Isotopes and other related data will be generated from sampling at selected precipitation stations on a temporal basis with distribution maps of N-isotopes in precipitation becoming available as a potential source of nitrogen pollution in water systems. The project also anticipates improved best-practise guidelines on integrating N-isotopes and hydro-meteorological approaches for the identification of nitrogen sources and pathways. If determined to be significant, N data will be incorporated into the GNIP framework. These results may contribute to national programmes to increase water use efficiency as foreseen in SDG6.4 “to improve water quality by reducing pollution”. For further information or questions please contact Ms Ioannis Matiatos ([I.Matiatos@iaea.org](mailto:I.Matiatos@iaea.org)).

*Incorporating isotope and geochemical tools allows a much faster and better characterization of the local water cycle, often providing key /unique information, required for water management*



### CRP F33025: Isotope techniques for the evaluation of water sources in irrigation systems

Despite recent improvements and developments in agricultural practices, irrigation still represents 70% of global water withdrawals. Most groundwater systems used for this purpose are poorly characterized, often leading to the unsustainable management of these valuable resources for water and food security. In most cases, aquifers are exploited for irrigation at rates much higher than natural replenishment rates leading to a rapid decline in groundwater levels and water quality deterioration. Therefore, a more precise knowledge of sources of water and estimates of recharge rates, as well as groundwater age to know how fast the aquifer is being replenished are important aspects to assess future water availability and sustainability of these resources. This new CRP aims to improve capabilities and expertise among Member States in the use of environmental isotopes techniques for better assessment and mapping of water sources for improved irrigation efficiency and sustainable water management in irrigated areas.

This CPR follows the success of F32005 “*Quantification of Hydrological Fluxes in Irrigated Lands Using Isotopes for Improved Water Use Efficiency*”, completed in 2014 with findings that clearly indicated the large effect of irrigation practices on water use efficiency, including deep drainage pulses that occurred after irrigation events that had no benefit to the crops and could potentially transport fertilizers and other contaminants to groundwater. The expected results of the new CRP are new knowledge about the combined use of conventional and isotope tools, including groundwater flow modelling, for a comprehensive characterization of irrigation systems involving many sources of water (including various local sources, grey-water and water imported from other basins), along with maps, cross-sections and

visualization tools highlighting the main features and findings for water managers. Best-practice will be reflected in new guidelines on integrating environmental isotopes and other indicators for sustainable use of the available water resources in irrigated areas. Hydrological and geochemical databases will also be established or upgraded for future monitoring purposes. These results may contribute to national programmes to increase water use efficiency as foreseen in SDG6.4 ‘substantially increase water-use efficiency’. For further information or questions please contact Mr Umayya Doss Saravana Kumar ([U.D.Saravana-Kumar@iaea.org](mailto:U.D.Saravana-Kumar@iaea.org))

### CRP: F31005: Isotope-enabled Models for Improved Estimates of Water Balance in Catchments

Increasing interest among water policy experts, particularly in arid/semi-arid tropical regions, to understand possible impacts of climate change on water resources is driving the development and use of environmental isotopes for improving catchment and lake water balance simulations. However, a proper monitoring program needs to be put in place to collect such critical data and models need to be tested at various scales to improve their use in water resources management and scenario analysis on climate change impacts.

This new CRP focuses on these questions and follows the successful of F31004: “Stable isotopes in precipitation and paleoclimatic archives in tropical areas to improve regional hydrological and climatic impact models” that sought to better understand processes that control isotopic signatures in precipitation especially in tropical regions. The new CPR is intended to test the new water balance model — IWBMiso and similar models — at scales from basins to catchment level, and further develop use of two large data networks: the Global Network of Isotopes in Rivers (GNIR) and Global Network of Isotopes in Precipitation (GNIP). The results of this CRP are expected to enhance simulation capabilities within: RAF8042 “Mainstreaming groundwater considerations into the Integrated Management of the Nile River Basin”, strengthen the IWAVE methodology employed in RAF7019 “Adding the Groundwater Dimension to the Understanding and Management of Shared Water Resources in the Sahel Region”, and; RLA 7024 “Integrating Isotope Hydrology in National Comprehensive Water Resources Assessments”.

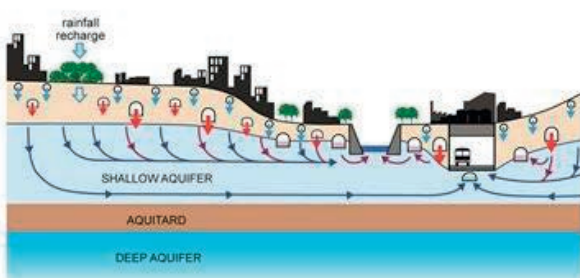
This CRP is expected to result in the consolidation of the stable water isotope database for precipitation, vapour, rivers, shallow groundwater and wetlands; improve methodology on integrating environmental isotopes in climate and hydrological models so as to improve model outputs and scenario analysis, and; improve capacity in Member States for the application of advanced modelling techniques for water resources management through collaboration and knowledge transfer. These results could make important contributions to national programmes to understand climate change impacts as foreseen in SDG13.3 — “Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning”. For further information or questions please contact Mr Dagnachew Belachew ([D.Belachew@iaea.org](mailto:D.Belachew@iaea.org))

#### **CRP F33024: Use of Isotope Techniques for the Evaluation of Water Sources for Domestic Supply in Urban Areas**

Development of large urban centres (megacities) is causing major health and water security problems around the world. Examples include intensive pumping and economic costs, overexploitation of local sources, water quality deterioration (wastewater from domestic and industrial uses, leakages, etc.), and poor sanitation and hygiene conditions resulting from water and vector borne diseases. These impacts have heavily disturbed the local water cycle (water balance, interactions, water quality) and led to urgent need to understand and advance current local, regional and global approaches to address these issues as well as sustainably exploit groundwater as a key resource in drought conditions.

The objective of this new CRP is to develop, test and integrate new methodologies and capabilities in Member States to better assess, map and manage water resources used for domestic water supply in urban environments.

Better understanding of the impact of urbanization on the local hydrological cycle in urban areas provides an important asset in the selection of water sources for domestic water supply. The guidance and tools



resulting from this CPR will illustrate the combined use of various applications (conventional, isotope, modelling) for a comprehensive characterization of urban environments involving many sources of water and enable production of maps, cross-sections and hydrological and geochemical databases for monitoring and visualization will highlight the main outputs and findings for urban water managers. These results may contribute to national programmes to improve urban water management as foreseen in SDG6.4 “Ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity”. For further information or questions please contact Ms Lucia Ortega ([L.Ortega@iaea.org](mailto:L.Ortega@iaea.org)).

### **First IWBMiso training event in Uganda**

Presentations on water resources issues in Uganda were made by experts from the different water management zones (WMZ). Issues related to better management of water resources (rivers, groundwater, lakes, springs etc.), need for data and knowledge, and the role isotopes in these were presented by IAEA was followed by discussion on understanding of gaps in data, collaboration between national institutes and international organizations. Lectures and discussions on the importance of water resources and water quality monitoring networks, monitoring techniques and policy by the USGS experts generated discussions and knowledge sharing amongst the participants. Presentations on application of remote sensing for groundwater mapping, evapotranspiration assessment and land cover mapping gave insight to the role of these technologies in water resources mapping and management. The demonstration workshop on iWBMiso was a good example of the application of



*Demonstration workshop on IWBMiso in Uganda.*



*A field trip to survey monitoring wells completed the training on iWBMIso*

isotope techniques to better constrain and validate water balance models in view of improving the quantification of the different water balance components. Many of the workshop participants seeking to apply the model requested help from the Agency for hands-on training on the tool.

The laboratory visit provided a very good insight into the current status of water analytical facility in Uganda. The water analysis lab hosts a number of state-of-the-art equipment with well trained technicians. The instruments, including the IAEA-provided LGR water isotope analyser are hosted in a relatively tight space. The isotope facility requires maintenance and new stable and tritium isotopes analytical facility may be considered in the medium-term.

About 30 high level experts from the Ministry of Water and Environment, from Makerere University, various water management zones and the NBI participated in the workshop.

A new CRP to expand the level and scope of IWBMiso has been approved that seeks to confirm the use of GNIR and GNIP at increased scales from basins to catchment levels and will start in 2018.

*R. Kastens, D. Belachew*

## **The Philippines expands IWAVE pilot project to additional water stressed regions**

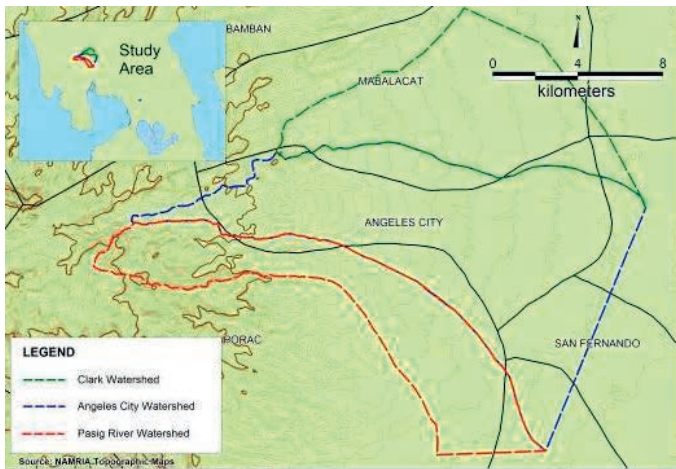
The Philippine National Groundwater Resource and Vulnerability Assessment project, conducted under the IWAVE Pilot Study 2011-2014, has been expanded to

additional water stressed zones including Angeles City and Mabalacat water districts with the support of an IAEA-supported expert mission to help conduct sampling campaigns for urban hydrology and advice aimed at strengthening water resource assessment capabilities. Specific objectives of the mission included:

- To discuss how hydrological problems guide planning and design of fieldwork,
- To demonstrate sampling techniques for relevant isotopes and chemistry,
- To assist in the implementation and management of field monitoring and sampling campaigns and facilitate collection of isotopic data.
- To initiate preliminary interpretation of field data and assessment of analytical options.

The expert undertook duties to strengthen skills and understanding of the technical context for sampling and monitoring and to assure timely availability of data and analysis. The mission also encompassed discussions with counterparts and senior staff, assessment of human resources and laboratory infrastructure, designing the field work, and field visits for demonstration and collection of 20-40 samples for isotopes and chemistry as well as on-site measurements. The focus areas are proposed to be Metro Manila, Metro Cebu, Davao City, Baguio City, Angeles City, Bacolod City, Zamboanga City, Cagayan de Oro City and Iloilo City as well as completion of isotope data acquisition for Water Resources Regions 2 and 10.

Discussions focused on proper guidance for application of isotope techniques to hydrological problems, conceptualization and design of field work, hands-on demonstration of sampling techniques and on-site measurements as well as assistance in sampling procedures and precautions as necessary and with proper consideration of monitoring requirements. Discussions were both specific and conceptual so as to enable additional sampling campaigns in other study areas. Prior to the interactive field exercises and selection of representative sample sites, inventory of wells and water points plus other background information on the study area(s), were collected, including topographic and other maps. This background information enabled discussions and substantiate importance aspects of planning field campaigns such as quality control and quality assurance (QA/QC) in analyses of samples, precautions and risk management, thoroughness in data collection and compilation, and the preparation of maps and plots.



Top: Philippines Fishing Boat in Angeles City, Bottom: Location of the field area – Angeles City and surrounding areas.

This exercise involving staff for hands-on field work was useful for skill development and guidance.

One of the basic problems facing NWRB is the lack of conceptual understanding and operational experience in fieldwork resulting in the lack of isotope data to initiate ground flow and complete assessments for water stressed aquifers. Isotope analysis of samples ( $^{18}\text{O}$ ,  $^2\text{H}$  and tritium) were performed at the Isotope Hydrology Laboratory of the IAEA and at the Philippines Nuclear Research Institute Environmental Laboratory, Quezon Philippines. A follow-up sampling campaign during rainy season is planned for 2018 year.

R. Kastens

## Symposia to introduce IWAVE in Asia and Pacific Region

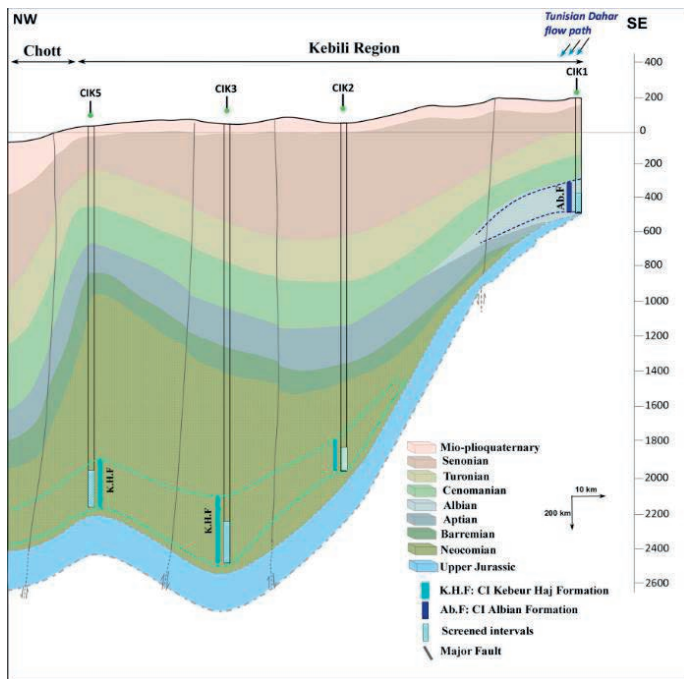
With the Board of Governors approval of the second phase of the IWAVE ‘mainstreaming’ projects (RAF7019 and RLA7024) in Africa and Latin America and Caribbean, there is interest from Asia and Pacific Member States to understand the approach and test its

application in the region. The IWAVE methodology is unconventional from standpoint of traditional technical cooperation because it seeks to establish the analytical and prerequisite requirements for using isotopes in groundwater assessments with the aim of increasing water availability — the goal of SDG6. This analytical step produces a national hydrological ‘sketch’ representing gaps in knowledge and technical capabilities that provides a blue print for conventional capacity building — driven by specific and priority data and interpretation requirements. Implementing the IWAVE framework in Asia and Pacific completes a comprehensive management structure committed to strengthening Member States capabilities to undertake comprehensive water resource assessment that will help increase water availability and thereby achieve SDG6. The event is tentatively scheduled for spring 2019, with venues under discussion with partner organization in the region. An announcement will be contained in the next IHS Newsletter.

R. Kastens

## $^{81}\text{Kr}$ dating of the North-Western Sahara Aquifer System (NWSAS)

As in many arid and semi-arid countries, Tunisia is facing the problems of effective water resources management, integrated and sustainable conservation, protection to meet growing demand, future needs and control risks. In order to properly manage the potential resources, Tunisia has taken up the challenge of mobilizing resources for water to serve the socio-economic development and welfare of its population. It also has implemented water policies and strategies with corresponding action plans for the protection and enhancement of its water resources and to manage the deficit between supply and demand. One of the major issues is the effective management of transboundary groundwater resources namely the North-Western Sahara Aquifer System (NWSAS) which is shared by Algeria, Tunisia and Libya. Extending over an area of more than one million  $\text{km}^2$ , this system is composed by two major aquifers: the Continental Intercalaire (CI) and the Complex Terminal (CT) which have allowed the development of oases and irrigated areas in desert regions. The mining of this fossil groundwater has led to the decline of the hydraulic head, increased pumping cost, and the deterioration of the quality of the water. In order to assess such fossil resource and to establish a dialogue mechanism between the three countries, the Observatory of Sahara and Sahel organization has implemented a new project for the elaboration of a



Geological cross section of the study area in Tunisia.

groundwater flow model to help in the management of the water resources of the NWSAS.

Dating groundwater, particularly on time scales greater than few decades poses challenges due to the heterogeneity of the geological and hydrological properties of these aquifers. For example, the use of  $^{14}\text{C}$  to date groundwater requires the application of geochemical models which can introduce systemic errors in the estimated residence times. Additionally, the interpretation of  $^{36}\text{Cl}$ , which used for residence times which are outside the dating range of  $^{14}\text{C}$ , is problematic due to the unknown origin of groundwater salinity in deep groundwater (Phillips, 2000; Love et al., 2000). Under these conditions, the application of inert tracers such noble gases radionuclide as  $^{81}\text{Kr}$ , present in very old groundwater are excellent tools to estimate groundwater ages and dynamics (Collon et al., 2000; Sturchio et al., 2004). Recent development of the Atom Trap Trace Analysis of the long-lived radionuclide krypton isotope ( $^{81}\text{Kr}$ ,  $T_{1/2} = 229\,000$  years) enabled quantification of the ultralow isotopic abundance of  $<10^{-12}$  ( $^{81}\text{Kr}/\text{Kr}$  ratio) in gases dissolved in groundwater, which permits age dating of time scales up to 1 million years, leading to a recognition that many deep aquifers in semi-arid and arid regions are much older than ages datable by radiocarbon method (e.g., Sturchio et al., 2004; Aggarwal et al., 2015).

The newly available  $^{81}\text{Kr}$  ages from the C.I. aquifer in Tunisia permitted to calibrate initial  $^{36}\text{Cl}/\text{Cl}$  and  $\text{Cl}$  contents (thus the effect of chloride dissolution) in

individual samples, showing the clearer view on the groundwater age structure of the Continental Intercalaire (C.I.) aquifer. However, the procedure still ignores the possible addition of the 'live'  $^{36}\text{Cl}$  from chloride, and ignoring this effect should result in underestimated  $^{36}\text{Cl}$  ages. In addition, provided that the estimate of the initial  $^{36}\text{Cl}/\text{Cl}$  is about twice as large as  $^{36}\text{Cl}/\text{Cl}$  in the present-day soil samples from the near recharge area (Guendouz and Michelot, 2006), it is probable that  $^{36}\text{Cl}/\text{Cl}$  ratios can be variable over the entire recharge history of the C.I. aquifer. In this respect, for the groundwater dating purpose beyond the radiocarbon application limit. It is advisable to consider using the  $^{81}\text{Kr}$  method.  $^{36}\text{Cl}$  analysis could be more useful, if combined with a firm chronological constraint from the  $^{81}\text{Kr}$ , to reconstruct the  $^{36}\text{Cl}/\text{Cl}$  ratio as this ratio itself is a useful paleo-environmental proxy.

K. Zouari, Ecole Nationale d'Ingénieurs de Sfax, Tunisia

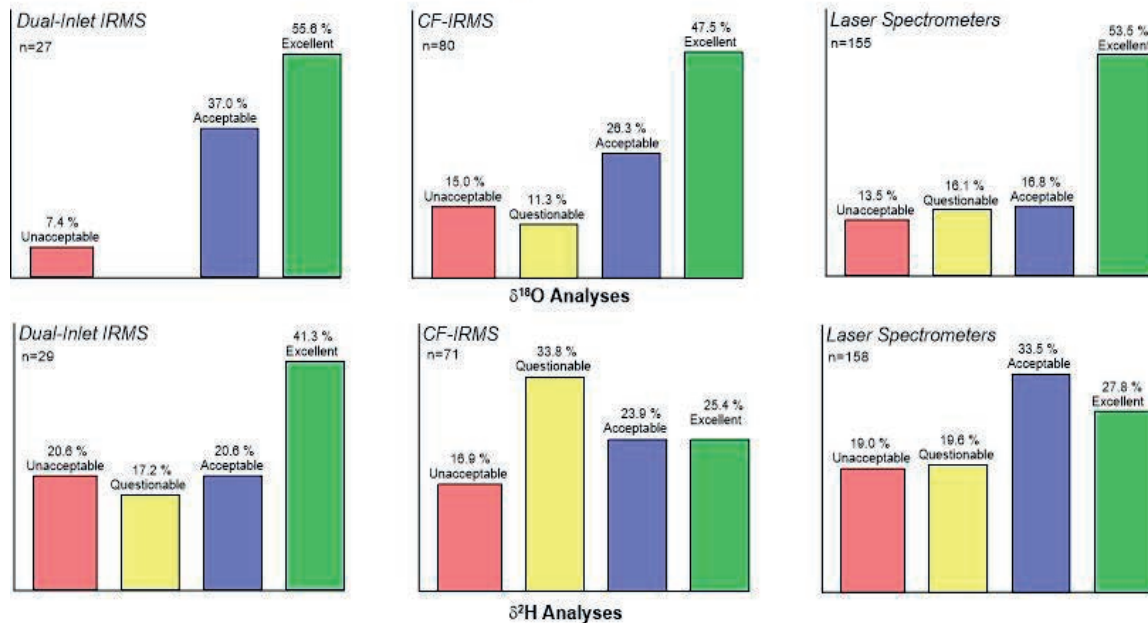
R. Kastens

## Ensuring proper performance of national isotope laboratories – QA services from the Isotope Hydrology Laboratory

Sound management of water resources is essential to human health, environmental sustainability, and economic prosperity. Isotopic techniques play a key role in the provision of scientific information to help inform water management strategies to improve the supply and quality of freshwater. One of the most widely used isotopic tool is the stable oxygen and hydrogen isotope contents of water; they give quantitative and important scientific information about water sources, age and hydrologic processes affecting the hydrologic cycles, like droughts or climate change.

Sound information for water resource decision making requires accurate and reliable water isotope data. To help Member State laboratories achieve top isotope results, the Isotope Hydrology Laboratory routinely conducts proficiency tests - the recent Water Isotope Inter-comparison (WICO) test included participation from 235 international laboratories that conducted analyses of 8 test samples by isotope-ratio mass spectrometry and laser spectroscopy (LAS). This response represents a 210 % increase over WICO 2002 and 75 % increase over WICO2011, with participants using laser spectroscopy analyzers increasing by over 100 %.

### Combined Accuracy Score for WICO Core Set



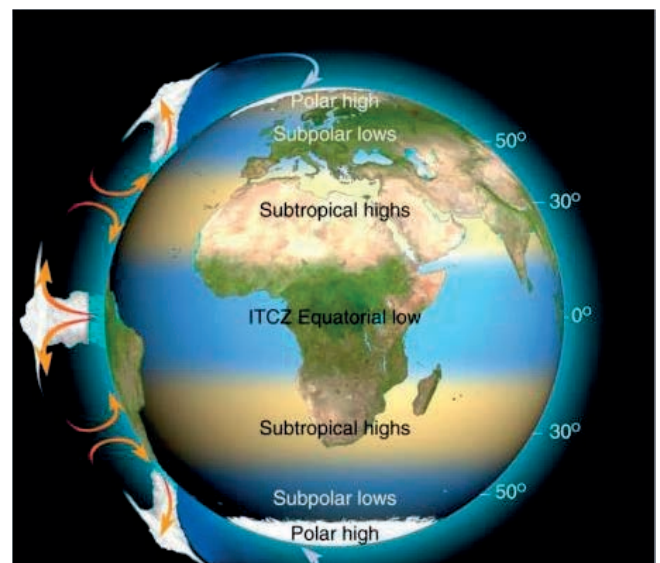
Results revealed that around 25 % of participating international laboratories did not perform as well as expected. Performance issues stemmed from skill- and knowledge-based errors such as calculation mistakes, compromised laboratory standards, and poorly performing instrumentation. To counteract these common mistakes, the IAEA recommends two key preventative steps; all water isotope assays should include 1–2 known control standards, and data runs should be carefully screened for contamination.

Combined, these two steps immediately inform the laboratory if fundamental mistakes were made or if samples were compromised. Member State laboratory feedback from the inter-comparison test is extremely important. Laboratories that performed poorly were able to quickly identify laboratory problems and to take corrective action to improve confidence in their results. The Isotope Hydrology section will continue conducting water isotope proficiency tests and other services in order to ensure that Member States perform the quality assurance and control necessary to successfully apply isotopic methods to assess their water resources.

R. Kastens, L. Wassenaar

## Isotope data may answer whether Brewer-Dobson circulation is speeding up due to climate change

An atmospheric “pump” driven by the stratospheric Brewer-Dobson Circulation (BDC) has a significant



Heat, vapour and ozone are transferred from mid-latitudes to polar latitudes through 3 ‘cells’ and the Dobson-Brewer circulation

impact on the Earth’s climate. The BDC is the slow circulation of the stratosphere – the part of the earth’s atmosphere above 12-18 km – with air moving upward in the tropics and poleward and downward at higher latitudes. Below the stratosphere lie the troposphere and then the planetary boundary layer. The atmospheric “pump” controls the distribution of ozone by bringing stratospheric ozone downwards and removing ozone-destroying chemicals out of the troposphere. It also brings dry, stratospheric air into the troposphere and affects the nature and intensity of rain and snow on the Earth’s surface, playing an important role in projections for climate change.

Climate models uniformly project an increase in the BDC in response to anthropogenic forces, but differ significantly in explaining how this change affects the stratosphere-troposphere interaction. An observational study [1] published in the Journal of Climate concludes that temperature observations do not reveal statistically significant trends in the BDC over the period from 1979 to the present. It is obviously important that atmospheric models contain data substantiating the interaction between the stratosphere and the troposphere.

New thinking about isotope distribution in rain and snow suggests that isotopes of oxygen and hydrogen carry a stratospheric signature that can be used to validate changes in the BDC and to monitor future variations. As these findings take root, isotopes in ice cores would allow a better understanding of past changes in stratospheric fluxes and help improve climate models.

*P. Aggarwal, R. Kastens*

[1] Ossó, Albert, et al. "How Robust Are Trends in the Brewer–Dobson Circulation Derived from Observed Stratospheric Temperatures?" *Journal of Climate* 28.8 (2015): 3024-3040.

## Technical Meeting on Nitrogen and Isotopes in Atmospheric Waters

A Technical Meeting on “Nitrogen and Isotopes in Atmospheric Waters” was held at the IAEA Headquarters in Vienna, Austria from 27 to 29 September 2017. The purpose of the meeting was to exchange knowledge and discuss gaps and current practices related to the release of nitrogen compounds in the atmosphere and their impact in the terrestrial environment and aquatic systems through wet deposition. The amount of reactive nitrogen gaseous compounds, such as ammonia (NH<sub>3</sub>), nitrogen oxides (NO<sub>x</sub>) and nitrate (NO<sub>3</sub>) have doubled in the atmosphere over pre-industrial times due to emissions mostly related to anthropogenic activities, such as industries that produce agricultural fertilizers, agriculture due to excess fertilizer application,

combustion of fossil fuels in transportation and the energy industry, and excessive animal livestock.

Disruption of N-balance, eutrophication in rivers and lakes, and stream acidification are a few of the negative consequences, when N-deposition exceeds the remediation capacity or critical load of the aquatic system. For this reason, the Isotope Hydrology Section organized a meeting involving experts from developed and developing countries, to identify current nitrogen monitoring practices and to explore how nitrogen and oxygen isotopes can be used to better define the contribution of atmospheric nitrogen in the degradation of water resources. The participants briefly reviewed the basic principles of N-emissions, transport and deposition processes, highlighted the effects of nitrogen deposition on ecosystems and water resources, and presented current wet deposition sampling techniques and the status of monitoring networks. The participants stressed the existing approaches to understand the cycling of nitrogen compounds in the atmosphere, their linkage with anthropogenic emissions and subsequent oxidation products, and their spatial and temporal distributions in the atmosphere. They also confirmed the priority areas and provided recommendations on how to improve data quality and expand the monitoring networks to areas not adequately covered, especially in Asia and Africa. The goal of the meeting was to get a perception of the key challenges in nitrogen wet deposition, so that the IAEA can assist Member States in incorporating stable isotopes to better address quality deterioration in water resources. For further information, contact Mr. Ioannis Matiatos ([I.Matiatos@iaea.org](mailto:I.Matiatos@iaea.org)).

*I. Matiatos*

## Impressum

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