WATER & ENVIRONMENT NEWSLETTER

A newsletter of the
Isotope Hydrology Section
International Atomic Energy Agency
Vienna

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CONTENTS

Abdelmoumen Dam, Morocco (credit: C.B.Gaye/IAEA)

INSIDE THIS ISSUE

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FROM THE SECTION HEAD...

Dear colleagues,

This issue of Water and Environment Newsletter is being released to coincide with World Water Day on 22 March 2002. The UN General Assembly in 1992 resolved to observe 22 March of each year as the World Water Day to raise public awareness of freshwater issues. The theme for the WWD this year is 'Water for Development' and the IAEA, for the first time, is the lead agency for coordinating UN system's activities for this day. By being the lead agency, a greater awareness is also being achieved on the role of IAEA in the water sector and on the role of isotopes in hydrology. The IAEA is hosting a WWD website (http://www.waterday2002.iaea.org) for news and information about issues related to water and development around the world. A students' art exhibition has been organized between schools in Austria and Uganda and the resulting materials will be displayed at a discussion and exhibition that will be held at the IAEA Headquarters on 22 March 2002.

The IAEA has played a pivotal role in promoting and expanding the field of isotope hydrology over the last four decades. Isotope hydrology today is practiced in most countries although the field began nearly 50 years ago with a few research centres in the developed countries involved in understanding the distribution of isotopes in natural waters. The number of analytical facilities has increased steadily as indicated by the increasing number of laboratories participating in IAEA's inter-laboratory comparisons (Figure 1). A significant number of these laboratories in the developing countries have been established with IAEA's support. In addition to geographical spread, the sheer number of hydrological studies with isotopes has shown a substantial increase (Figure 2). Isotopes were used in less than 100 reports of hydrological research and applications in major scientific journals in the period 1960 to 1965. During 1995-2000, however, more than 7000 such reports were published. The primary field of application in the early reports was related to groundwater, but applications in climate change studies, that were nearly nonexistent in 1960, grew to be nearly equal to groundwater applications in 1995-2000.

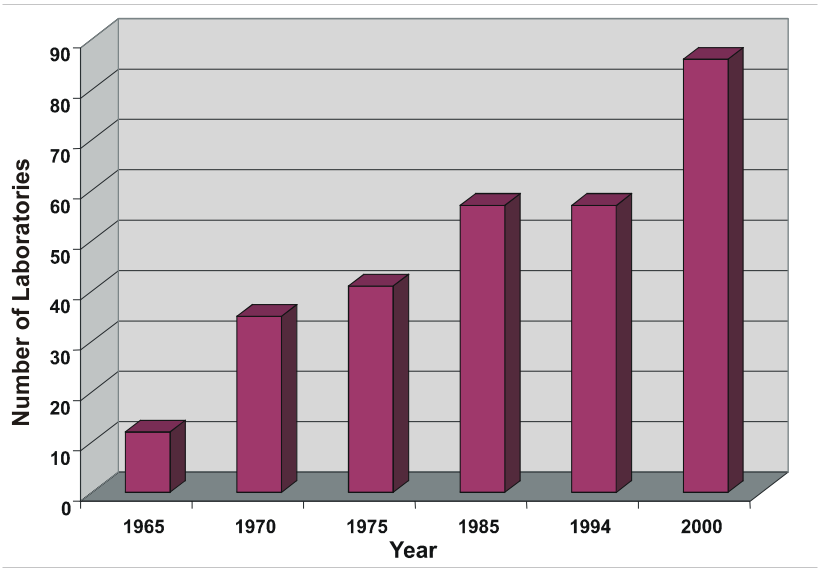

Figure 1. Number of laboratories participating in IAEA interlaboratory comparison exercises on Tritium measurement

Continuing activities in the IAEA's isotope hydrology programme facilitate further developments through research, information dissemination, and support for field applications. Some of recent examples of international cooperation include those in Bangladesh, Latin America, and Yemen. In all instances, the IAEA facilitated the integration of isotope techniques in World Bank-led large projects to

provide critical hydrological information in a cost-effective manner. Without the IAEA's intervention, such international cooperation rarely is possible in projects involving multiple agencies and/or countries.

During the past year, we took several initiatives to focus our programme towards developing isotope applications for global issues of water resources management. One of the greatest issues in hydrologic sciences today is the sustainability of water resources in the face of increasing demand, urbanization, and depletion or pollution of existing resources. Nearly half of all freshwater used for drinking and irrigation worldwide is derived from groundwater aquifers, linking the sustainability of groundwater resources to sustainable human development. However, groundwater resources in many parts of the world are severely stressed, as witnessed by declining water levels. The role of isotopes as indicators of groundwater sustainability was reviewed at an Advisory Group meeting held in co-operation with UNESCO. The meeting identified the complementary, but critical, role of isotopes in improving methods for groundwater sustainability assessments.

Current estimates of the world's water resources are generally weak as regards groundwater components, and no information is available as to what proportions

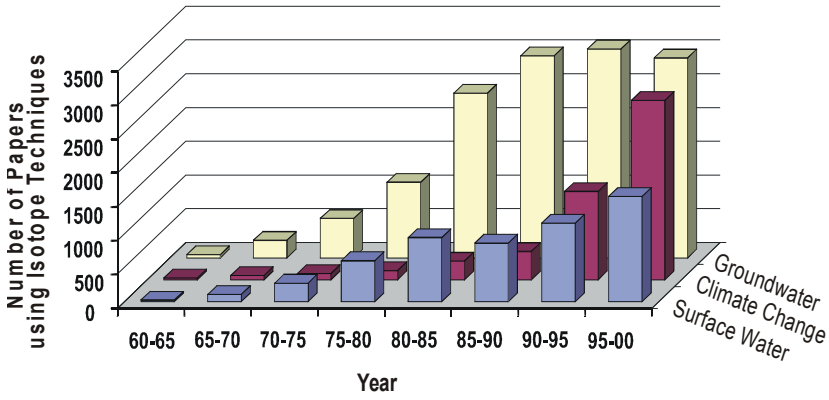

Figure 2. Number of publications using isotope techniques in hydrology

of the groundwater bodies are renewable or non-renewable. A joint project with UNESCO was recently initiated to use extensive isotope data from groundwater aquifers worldwide, most of which have been collected as part of the Agency projects. The aim is to improve the understanding of the global distribution and amounts of non-renewable ground-waters, incorporating this information into a series of GIS-based maps. These maps and other isotope-based indicators of groundwater sustainability will be integrated into the World Water Development Report (WWDR) to be produced on behalf of the entire United Nations system.

Estimation of the renewable groundwater resources and related hydrological processes is critically dependent upon determining the age of modern groundwater. As bomb tritium has now been essentially washed out of the atmosphere, this ideal tool for characterizing the presence of modern groundwater is becoming difficult or impossible to use. While tritiogenic helium-3 offers a similar or better tool as tritium did, helium-3 measurements require expensive and high-maintenance mass spectrometry. This has kept helium-3 measurement facilities and applications in a limited number of laboratories even though hydrologic applications of helium-3 have been recognized for over 20 years. In order to facilitate further developments in this field, applications in hydrology, we have decided to establish a helium-3 facility at our laboratory here in Vienna. The mass spectrometer has been ordered and is expected to be delivered by early 2003. The inlet system and related accessory instrumentation are now being acquired. We expect the laboratory to un-

dergo operational testing in 2003 and be ready for routine applications in 2004.

Climate change impacts on water resources are potentially significant and need to be a part of comprehensive water sustainability strategies. Isotopes are indispensable tools for understanding past climate change and impacts on the hydrological cycle. The GNIP database has been a critical resource for isotope applications in climate studies. Isotopic composition of precipitation has provided a new dimension for Atmospheric Global Circulation Models (AGCMs) that are used for reconstructing paleoclimatic conditions in support of research on global change. Institutions in Germany, France, and the United States recently have expanded the use of global isotope data of precipitation to better represent and verify the simulation of hydrological processes in AGCMs. Models based on isotope data have improved process understanding and are considered more reliable.

While it has been recognized for some time that isotope monitoring of river discharge will improve our understanding of climate change and continental-scale hydrological processes, these data have not been available so far. Recent efforts to map isotopes in river flow in the United States have further strengthened this argument. During 2001, we initiated a new coordinated research programme to collect and analyse isotope data from river waters world-wide for understanding hydrological processes in river basins.

In addition to scientific efforts, integration of isotopes into mainstream hydrology requires a closer interaction between the isotope hydrologists and the hydrological community at large. Progress has been made in the implementation of the IAEA-UNESCO Joint International Isotopes in Hydrology Programme (JIIHP) designed to foster cooperation between hydrologists and isotope professionals at the national level. A meeting was held at the IAEA Headquarters in Vienna to prepare background for technical and operational programme for JIIHP. The meeting was attended by representatives of the UNESCO, IAEA, and some of UNESCO's IHP (International Hydrological Programme) National Committees. The establishment of this important programme of action will ensure close links between the Agency's isotope hydrology programme and that of UNESCO's International Hydrological Programme (VI) from 2002 to 2007.

The 22nd meeting of the UN Administrative Committee on Co-ordination (ACC) – Subcommittee on Water Resources (SWR) was held in Geneva, Switzerland during September 2001. I was elected as the Chairman of the Subcommittee for its 23rd and 24th sessions, covering the period September 2002-September 2004. As this Subcommittee is the highest coordinating body in the UN system on water issues, it gives us, isotope hydrology community, an excellent platform to highlight our activities from. The UN General Assembly recently adopted a resolution designating the year 2003 as the International Year of Freshwater. As the Subcommittee Chairman, I would also Chair the coordinating committee being constituted for the UN system's activities in the International Year of Freshwater.

World Summit on Sustainable Development will be held at Johannesburg, South Africa, in August – September 2002. The inter-Agency committee would develop a brief and concise document on future water challenges that would feed into the Secretary General's report to the Summit. This document would also be used by the various agencies to coherently present future water resources challenges to their constituencies, as well as serve as an input for the International Year of Freshwater.

The achievements noted above reflect the collective efforts of a team of dedicated professionals in the Isotope Hydrology Section. As a result, the coming year also promises to be quite busy and important for integrating isotopes in hydrologic sciences.

Pradeep AGGARWAL

ISOTOPES IN INTEGRATED CLIMATE SYSTEM STUDIES

An Advisory Group Meeting on 'Isotopes in Integrated Climate System Studies' was held at Agency Headquarters during 18-20 November 2001 to consider and prioritize research opportunities at the carbon and water cycle intersection, including the current and future role of isotope science in the global, collaborative research programmes. The group comprised leading experts in water and carbon cycle research, from the fields of atmospheric and ocean dynamics, terrestrial energy/moisture budgets, ecosystem processes, global moisture budgets, soil processes, CO_2 and climate change.

Through discussions and presentations the participants emphasized that climate change due to anthropogenic influences such as greenhouse gas emissions and land use changes such as deforestation are expected to alter the water, carbon and related biogeochemical cycles which will inevitably affect present and future climate, including water resources availability. The global research community acknowledges that climate change impacts on water resources are potentially significant and need to be a part of comprehensive water sustainability strategies. Isotopes have played a vital role in tracing hydrological processes and in understanding the past and present-day water cycle. Models calibrated with input from isotope-based studies will also serve as valuable tools for predicting future climate changes. In addition to water cycle processes, isotopes can be useful for tracing origin of greenhouse gases, labelling of terrestrial ecosystem CO_2, and for characterization of methane originating from different sources. Recent efforts to understand isotope signatures in ecosystems have also revealed that they are inseparably linked back to the water cycle, an example of another feedback between water and carbon cycling an its impact on the climate system. The strong, recent interest in earth systems research is motivated by the integrated and interdependent nature of the earth's climate system.

The working group recommended to support symposia, workshops, experts meetings, and training courses for exchange of scientific ideas as well as to foster better linkages and awareness of activities between scientists working in carbon and water cycle research; to develop and expand links to large climate research programmes (e.g. WCRP); to expand and enhance education programmes in developing countries, and to support and promote studies that improve understanding of the linkages between the carbon and water cycles. The group proposed that a special session be dedicated to integrated climate system studies at the next IAEA Symposium in 2003.

A group photo of the participants
From Left to Right: J.J. Gibson (IAEA), S. Chambers (Australia), S.K. Bhattacharya (India), L. Martinelli (Brazil), P. Schlosser (USA), J. Ehleringer (USA), P. Aggarwal (IAEA), I. Levin (Germany), D. Yakir (Israel), K. Rozanski (Poland), T. Edwards (Canada), A. Sugimoto (Japan),R. Gonfinatini (Italy).

ISOTOPES IN THE WATER CYCLE MODELS

The International Atomic Energy Agency (the Agency) hosted an Advisory Group Meeting during 27-29 August 2001 on 'Application of Isotopes in Water Cycle Models (IWCM), bringing together a group of isotope hydrology modelling experts to discuss recent advances in the field as well as avenues for future development. The meeting focused on conceptual, analytical and numerical modelling of water cycle and climate processes at local to global scales, and applications, reviewing significant recent progress made in incorporation of isotopes in General Circulation Models (GCMs), Regional Climate Models (RCMs), land surface schemes, watershed hydrological models, lake basin models, and hill slope/catchment models.

To date, isotopes are operationally implemented in the ECHAM-4, GISS AGCM, and incorporation of isotopes in the Japanese FORSGC AGCM is under development. A version of the Swedish HBV hydrological model incorporating stable isotopes has also been tested at the small catchment scale to simulate isographs (isotope hydrographs), and has been used to develop more realistic hydrological parameterization schemes based on a "soft data" optimization procedure. Three Global Energy and Water Cycle Experiment (GEWEX) studies have identified strategies for incorporation of isotopes into their observational and modelling programmes for model development and validation. These large projects include GAPP (USA), MAGS (Canada) and GAME (Japan). GEWEX GAPP studies include a DOE-supported water cycle pilot study involving incorporation of isotopes into a mesoscale atmospheric model (MM5) and land surface models (NCAR-LSM, TOPMODEL, TOPLATS). This 10-year research programme also plans to develop a new cloud microphysics model with isotope mixing ratios, to be coupled to the land surface scheme, and involves a parallel data collection network in the Walnut Creek Watershed (~75 x 100 km). The GEWEX MAGS Study has focused for 5 years on collection of isotopes in discharge and related hydrologic components in the Liard Basin (277000 km^2) and 5 tributaries basins ranging from 200 km^2 to 2050 km^2 for evaluating the WATFLOOD hydrological models, although direct incorporation of isotopes in the model has not yet been initiated. Isotope tracer capability in the Japanese GCM has been implemented and is undergoing further refinement. Also, collection of comprehensive isotope dataset for hydrological model development remains a focus of GAME.

The introduction of water isotopes in "earth system models" that fully couple the atmospheric, oceanic, chemical and biological subsystems of the earth, will open a wide range of applications for the water isotopes in many different fields. Some applications include: 1) verification of the hydrological processes in these models; 2) estimating natural variability on longer time scales (larger than 100 years); 3) cross links of the water cycle with the carbon cycle; 4) interpretation of palaeoclimate archives. The consensus of the participants was that great potential exists for application of isotopes in hydrological models at the continental scale, relevant to study of large basins (Mississippi, Mackenzie, Amazon, Lena, etc.) although such models have not yet been developed and applied. Coupling of continental scale hydrological models with GCMs, including incorporation of evapotranspiration feedbacks to the atmosphere, could potentially improve the realism of the GCMs water and tracer fluxes. Likewise, such a coupled approach could benefit the study of hydrological processes and isotope distribution at the continental scale, and could serve as a model diagnostic variable. The working group recommended to support a study or CRP to incorporate isotopes into a continental scale hydrological model(s) that can be coupled to atmospheric GCMs/RCMs and that can be used independently to predict isotopic changes in the basin water cycle. Follow-up activities will include a Symposium on "Isotope Tracers in Water Cycle Models" at the next IUGG/IAHS meeting in Sapporo, Japan in 2003. This will ensure wider interest and ongoing support for the initiative within the scientific community.

NOBLE GAS ISOTOPES IN GEOTHERMAL EXPLORATION AND MONITORING

To discuss state of the art and development needs of application of noble gas isotopes in geothermal exploration and reservoir monitoring, the Agency organized an Advisory Group Meeting in Vienna during 25 - 28 June, 2001. Twelve scientists from China, Israel, Italy, Japan, Mexico, New Zealand, Switzerland, UK and USA participated in the meeting.

A group photo of the participants
Front row: G. Magro (Italy), P. Zhao (China), Y. Sano (Japan), B. Christenson (New Zealand), Z. Pang (IAEA)
Back row: H. Friedrichsen(Germany), R. Gonfiantini (Italy), R. J. Poreda (USA), M. Kennedy (USA), W. G. Darling (UK)

Isotopes of noble gases (He, Ne, Ar, Kr, Xe), in particular Helium ($^3He/^4He$), have been used as natural tracers in understanding the key issues affecting the efficient and sustainable development of a geothermal reservoir. These comprise mainly source and recharge of water and gaseous components; source and supply of heat; and geometry and permeability of the reservoir.

In the exploration phase, $^3He/^4He$ ratio has been widely used as a tool for geothermal heat source delineation due to the fact that distinctive values are found for crustal helium, with $^3He/^4He$ of $\sim10^{-8}$ and mantle helium, with $^3He/^4He$ of $\sim10^{-5}$. Geothermal systems situated on the subduction zones are found to contain higher ^3He as a result of mantle contribution during subduction. Noble gas isotopes provide normalization while estimating concentrations of temperature sensitive volatiles (e.g. CO_2, CH_4, H_2) and observing processes like phase separation and water-rock interaction. Information regarding age and temporal evolution of the geothermal system can be deduced from noble gas isotopes as well. Concentration and accumulation rates of radiogenic ^4He, ^{40}Ar, and nucleogenic ^{21}Ne provide measure of residence time of water. Noble gas abundances, e.g. ^{132}Xe, $^3He/^4He$, $^4He/^{40}Ar$ help in flow path determinations.

During production phase, for understanding the reservoir permeability and connectivity, techniques such as ^{82}Kr, ^{128}Xe as vapor phase tracers; Rn concentrations for fracture apertures are very useful. Reservoir performance, including boiling trends, fluid mixing, injectate return, and other temporal changes induced by production or natural processes can be understood by monitoring temporal and spatial changes in concentrations and relative abundances of noble gas components.

The group recommended the Agency to further promote the development of noble gas isotope techniques and their use in geothermal development projects. In order to facilitate dissemination of information, an outline of a technical publication on application of noble gas isotopes to geothermal development was drawn at the meeting.

ISOTOPE INDICATORS OF SUSTAINABILITY IN GROUNDWATER SYSTEMS

An AGM on Isotope Indicators of Sustainability in Groundwater Systems was held at Agency Headquarter during 15-17 October 2001 to discuss the use of isotopic methods in analysis of the groundwater sustainability problem. Specifically, the group was asked to contribute to the development of a set of well-defined indicator variables for defining, monitoring, and comparing stress on groundwater systems, and as a potential contribution to World Water Assessment Programme. A multidisciplinary team of groundwater specialists, many with experience in sustainability issues and others with expertise in application and integration of isotope techniques in hydrogeological investigations developed a scientific approach to the issue.

The following summary is an overview of the scope and definition of the issue, key scientific inputs, and recommendations as summarized by the group.

Groundwater sustainability relates to the long-term ability of the resource to provide key services (including environmental considerations). These sustainability issues can be subdivided into problems arising from groundwater abstraction and pollution loading from the land surface.

In the formulation of sustainable management strategies the following knowledge requirements arise: (i) determination of the aquifer recharge rates and their temporal and spatial variation (especially in arid and semi-arid environments), (ii) evaluating the age and origin of groundwater explored or abstracted and associated contaminants, (iii) determination of groundwater flow-fields, (iv) assessment of the spatial variations in aquifer vulnerability in relation to land use, and (v) identification of the three-dimensional distribution of deep, high quality palaeo-groundwater bodies, which represent potential strategic reserves.

Hydrogeology and related scientific disciplines, provides a wide range of methods to address these questions. However, due to complexity and inaccessibility of the subsurface, coordinated use of independent methods is required to arrive at a consistent and robust conceptual model of the physical and chemical characteristics of the groundwater system. In establishing such models, environmental tracers are extremely useful and, in some cases, the only means for obtaining the necessary knowledge. To guarantee that aquifer management profits from environmental tracer data the interface of data information to management models has to be strengthened. A number of good examples show that environmental tracer information can contribute to water resources assessment, planning and management.
The working group concluded that application of aquifer sustainability concept rests firmly on development of a sound scientific understanding of basic hydrogeological conditions, but at the same time needs to be integrated and interfaced with a broader and integrated framework for evaluating water resources and social needs as with indicator development sponsored by the World Water Assessment Programme (WWAP) of United Nations. The working group recommended that emphasis be placed on the application of a multi-tracer 'tool bundle' rather than to focus on individual or a limited set of environmental isotope techniques. Such a tool bundle is inherently adaptable to specific conditions of selected aquifer or watershed systems, and can be demonstrated through case studies. A combination of techniques is recommended to get more robust results that can best be demonstrated through compilation of case studies.

IAEA TRAINING COURSES IN ISOTOPE HYDROLOGY FOR AFRICA

In the framework of the IAEA Technical Cooperation project RAF/8/034, three regional training courses were organized by the Agency for the African region.

1. Basic Course on Isotope Hydrology, Sfax, Tunisia

A Basic Regional Training Course on Isotope Hydrology for French-speaking African Countries was organized by the Agency in collaboration with the Government of Tunisia and was held from 2 to 31 May 2001 at Sfax, Tunisia. The training was hosted by the Laboratories de Radio-Analyses et Environment of the Ecole Nationale d'Ingénieurs de Sfax (LRAE - ENIS). The objective of the course was to provide basic training in application of isotope hydrology techniques to staff from the Member States of the Africa region. The programme of the course covered the following main topics: Basic principles of Isotope Hydrology, Environmental Isotopes: use of stable and radioactive isotopes for water resources studies, and tracing techniques using artificial radioactive isotopes. 23 participants from Algeria, Cameroon, Democratic Republic of Congo, Gabon, Madagascar, Morocco, Niger, Senegal and Tunisia attended the course.

2. Regional Training Course for English Speaking countries, Windhoek, Namibia

The Department of Water Affairs, Ministry of Water, Agriculture and Rural Development hosted the Basic Training Course on Isotope Hydrology in collaboration with the Department of Geology, University of Namibia. The opening ceremony took place on 24 June 2001 at University of Namibia. Twenty-five trainees from 10 English-speaking countries, including four participants from Namibia attended the course that lasted till 20 July. The Agency experts, Prof. W. Mook from the Netherlands and Dr. A. Moulla from Algeria lectured at the course. The course included basic principles of isotope hydrology, applications of environmental and artificial isotopes for water resources.

3. Regional Advanced Training Course, Argonne, Chicago, USA

An advanced Training Course was organised at the Division of Educational Programs, Argonne National Laboratory, Chicago, USA during 10 - 28 September 2001. A total of 16 trainees from 9 African Member States participated in the course. The course emphasized a brief theoretical introduction on fundamentals of hydrochemistry and geochemical modelling followed by hands-on experience in use of geochemical models NETPATH and PHREEQC. The participants were encouraged to use data derived from various IAEA technical cooperation projects in their respective countries.

Editor's Note

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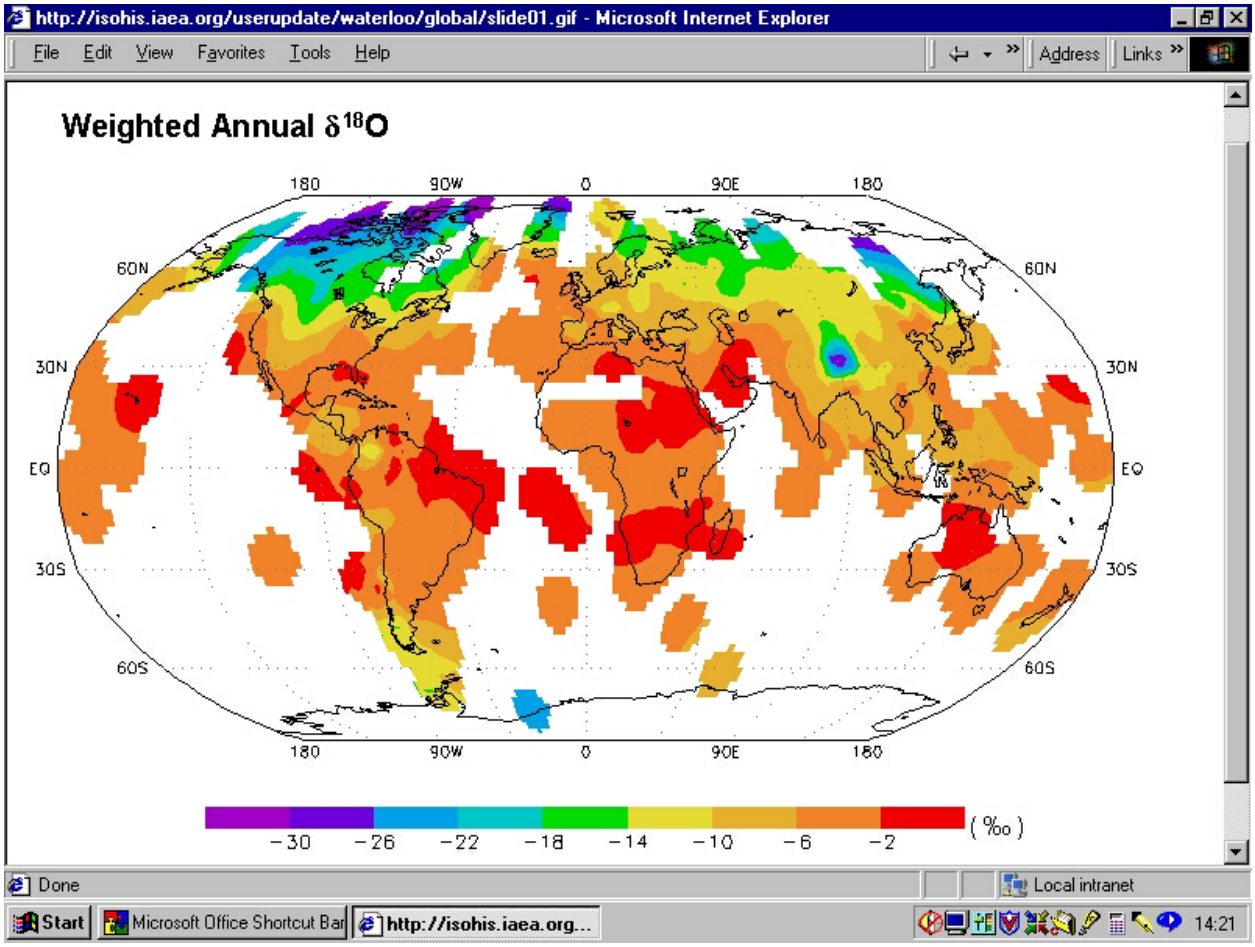
GNIP MAPS AND ANIMATIONS

The Agency has recently developed graphical representations of stable isotope data in the GNIP database to facilitate accessibility and increased use of the data, and to strengthen and improve interdisciplinary linkages to the network. The graphical representations provide a visual evaluation of the spatial and seasonal variations of isotope data and may be used for reference and teaching purposes. The "GNIP Maps and Animations" produced in cooperation with J. Birks and T. Edwards of the University of Waterloo, Canada, are available on Internet at the GNIP/ISOHIS Web page http://isohis.iaea.org.

A graphical GrADS-compatible version of the GNIP dataset was created to produce these maps and to enhance compatibility with the expanding array of grided climate-reanalysis data products. Interpolation of the data from the GNIP stations onto a global grid was performed using a Cressman objective analysis in GRid Analysis and Display System (GrADS).

The maps of weighted mean annual and monthly $\delta^{18}O$, $\delta^{2}H$ and d-excess in precipitation are available at regional and global scales. Global maps and animations of climate data such as 500mb wind, precipitable water with 500mb wind, surface temperature with 500mb wind were also created.



Global distribution of weighted annual mean of $\delta^{18}O$ in the precipitation

INVESTIGATING RIVER WATER CONTAMINATION IN ECUADOR

In Ecuador, the Quito Municipal Authority, is undertaking a water quality study for the Master Plan for Drinking Water and Sewage, including the most appropriate alternatives for sewage treatment in the metropolitan area. Within the framework of an IAEA Technical Cooperating project (ECU/8/020), re-aeration rate of main rivers crossing Quito was determined by employing isotope techniques.

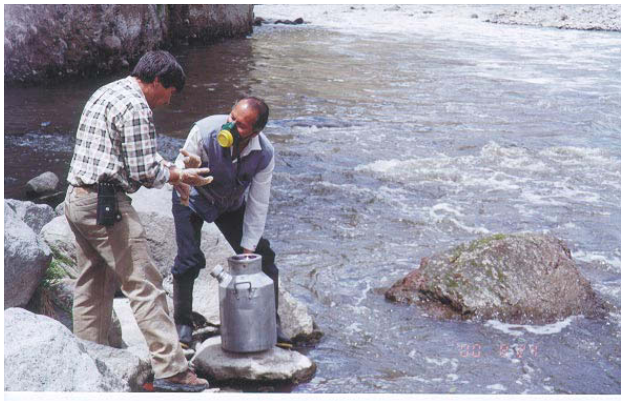
The ability of a stream to assimilate oxygen-demanding materials is in part controlled by the rate at which atmospheric oxygen is transferred into the stream. Re-aeration is used for transferring atmospheric oxygen to water body and re-aeration-rate coefficient (referred to as K_2) is the measure of efficacy of this transfer. K_2 can be estimated by several theoretical and empirical equations or measured *in situ* by experimental methods. Accurate knowledge of this re-aeration capacity is the key to successful pollution control. It is also an essential input for waste treatment requirements and thus is an inevitable prerequisite for estimation of the cost of pollution control.

The theoretical and empirical equations for determining K_2 were developed using data collected from small plain rivers. These methods were not satisfactory in cases such as high land rivers in Ecuador. It was therefore necessary to perform a fully independent direct measurement of the gas transfer and re-aeration capacity of natural streams.

Multi-tracer experiments, using a fluorescent dye Rhodamine-WT, tritiated water as dispersion indicator, and krypton-85 as a gaseous tracer, were carried out in different seasons and different sections of the Guayllabamba and Machangara rivers in February and August 2000.

Results show that the empirical formula gives values of K_2 ten times lower than those measured directly by tracer tests. These differences are due to the Andean characteristics of the rivers: high turbulence and strong hydraulic gradients.

The two-year project allowed the determination of river parameters such as flow, transport, dispersion and re-aeration rates. The information on re-aeration rates of the two highly contaminated rivers crossing the city of Quito will be used by the Environmental Authority of the Metropolitan District of Quito for determining the needs in water treatment. Through training and demonstration, the CEEA has acquired the ability to perform similar tracing tests.



Injection of the cocktail of tracers in the Machangara and Guayllabamba rivers

SUSTAINABLE MANAGEMENT OF GROUNDWATER IN LATIN AMERICA

In order to optimize the sustainable management of groundwater resources in the Latin American region, a regional project (RLA/8/031) has been initiated with an objective to study groundwater availability, quality, and pollution risks.

In this project, a multidisciplinary, interinstitutional activity to facilitate the regional cooperation, institutes from South and Central American Member States like Chile, Ecuador, Peru, Costa Rica, Colombia, Uruguay and Paraguay are participating.

The project will be supported by the use of isotope techniques as part of an integrated approach with other conventional techniques. The final stage of the project will comprise groundwater modelling to help develop groundwater management plans. A routine groundwater-monitoring programme will provide the necessary inputs for continuous improvement of mathematical models. The project will be implemented as a series of national subprojects focused on field activities at the country level. The regional component is designed to promote cooperation and exchange of information and experience among the Member States involved. The preparatory aspects were discussed during the first coordination meeting of the project. National coordinators and main hydrogeologists from the participating countries attended the meeting that took place in Santiago de Chile in June 2001.

In order to achieve the objectives of the project, one seminar and four regional practical training are envisaged. The main topics to be covered include basic hydrogeology, groundwater contamination and water resources management. A quality control exercise for laboratories performing chemical analyses will be carried out. A web page (http://www.udep.edu.pe/recursoshidricos), developed in Peru and expected to continue after the completion of the project, has been initiated under the project, not only to inform on RLA/8/031 activities, but also to help other Latin American institutes to perform similar studies. Regional training will be provided in isotope hydrogeology, groundwater modelling, contamination, and aquifer vulnerability. Seminars on sustainable management of water resources will be organized for the high-level water sector administrators.

ISOTOPE HYDROLOGY IN CHINA

The application of environmental isotope techniques to hydrology in China has achieved an important milestone with a special issue of the English language publication "Science in China". The special issue entitled "Water Resources Assessment: Isotope Techniques" was published in August 2001 in China by the Chinese Academy of Sciences (Science in China, Volume 44 Supplement, Series E, 192pp. ISSN 1006-9321). The volume comprises a total of 34 papers covering isotope applications in groundwater and hydrogeology, surface hydrology, unsaturated zone processes, climate and palaeoclimate, geothermal systems and analytical methods, demonstrating both the diversity and depth of capability. The special issue is an outcome of the 1st Chinese National Workshop on the Application of Isotope Techniques in Water Resources Assessment and Management that was held in Beijing in August 2000 with the support of the IAEA. The special issue is highly recommended as essential reading for researchers, practicing hydrologists, water resource managers and students who want to either grasp an overview or find details of the practice of isotope hydrology in China.

In recent months, further strengthening of the role of isotope hydrology in China has been achieved as a result of the establishment of the Chinese National Committee for the Application of Isotope Hydrological Techniques, which occurred in May 2001. The establishment of this Committee is a key step in the development of applications of isotope hydrology in China. It brings together high-level representatives of the two ministries in China charged with responsibility for water resources: the Ministry of Land and Resources and the Ministry of Water Resources, together with representatives of technical organizations (IGG/CAS and BRUIG), representatives of the nuclear agencies (CAEA and CNNC), in addition to the role of observer for the IAEA.

ON-GOING COORDINATED RESEARCH PROJECTS

Isotope Tracing of Hydrological Processes in Large River Basins (2002-2005)

Scientific Secretaries: Pradeep Aggarwal, John Gibson

This CRP supports a global network of isotope hydrology investigations focusing on water balance and water cycling processes in large river basins of the world. Isotope signals in river discharge are applied to investigate catchment-integrated processes, water origin and residence times, snowmelt, surface-groundwater exchange, evaporation-transpiration partitioning, precipitation variability, and climate/land use changes.

Application of Isotopes to the Assessment of Pollutant Behavior in the Unsaturated Zone for Groundwater Protection (2000-2005)

Scientific Secretaries: Pradeep Aggarwal, Kshitij Kulkarni

This CRP supports development of a comprehensive and coordinated approach to quantify biogeochemical processes related to pollutant transport in the unsaturated zone. A concentrated field effort at selected sites will be carried out to understand and quantify the interactions occurring within the unsaturated zone and the Saturated-Unsaturated Interface Region (SUIR).

Isotopic Composition of Precipitation in the Mediterranean Basin in Relation to Air Circulation Patterns and Climate (2000-2003)

Scientific Secretary: Laurence Gourcy

This CRP aims to identify and better define the interactions between climatic conditions and isotopic composition of precipitation in Mediterranean Basin, in order to assess the relative contribution of climatic parameters to overall climatic change experienced in the region, including decrease in precipitation.

Nuclear and Isotopic Techniques for the Characterization of Submarine Groundwater Discharge (SGD) in Coastal Zones (2002-2006)

Scientific Secretaries: Kshitij Kulkarni, Pavel Povinec (Monaco)

This CRP focuses on development of isotope techniques for estimating submarine groundwater discharge (SGD), characterization of SGD impacts on the coastal environment, and related coastal aquifer management issues. Isotopic techniques include ^{222}Rn, ^{226}Ra, ^{87}Sr, ^{3}He, ^{4}He, ^{3}H, ^{14}C and ^{234}U among others for assessing fluxes across the groundwater/marine interface. Geochemical and remote sensing techniques are also being explored as complementary tools.

Origin of Salinity and Impacts on Fresh Groundwater Resources: Optimization of Isotopic Techniques (2000-2004)

Scientific Secretary: Cheikh Gaye

This CRP aims to better understand the mechanisms of natural salinization of groundwater including the impact on exploitation of fresh water resources. The multinational study examines potential applications of stable and radioactive isotope tracers, with a focus on testing the methods in a case study of the Souss-Massa coastal plain in southwest Morocco.

Isotopic Response to Dynamic Changes in Groundwater Systems due to Long-term Exploitation (1999-2003)

Scientific Secretary: Bill Wallin

This CRP aims to assess long-term hydrodynamic changes in groundwater systems induced by exploitation. The objectives are to characterize the long-term isotopic and hydrochemical response of groundwater systems under stress, to assess changes in flow dynamics and pathways, mixing patterns, hydraulic inter-relationships, and mass transport characteristics, and to develop dynamic simulation models based on long-term isotope data to be used for predictive purposes.

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