WATER & ENVIRONMENT

N E W S

A Quarterly Newsletter of the IAEA Subprogramme on Development and Management of Water Resources

Photo credit: E. Gibert-Massault

Erg Chech in the Sahara desert (Algeria)

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IAEA SUB-PROGRAMME ON
DEVELOPMENT AND MANAGEMENT OF WATER RESOURCES
(1999-2000)

OBJECTIVES

- to assist in the wider use of isotope techniques in applied research and practical field applications related to sustainable development and optimum management of water resources;

- to provide support for effective integration of isotope methods in national activities in this field, and to promote research and field studies related to man - induced changes and their hydroclimatic impact on the water cycle and its interaction with other environmental systems.

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PROJECTS

Human Impact on Water Resources (F4.01)

- to further improve and enhance isotope methodologies applied to a wide spectrum of hydrological problems encountered as a result of water utilization practices that induce adverse effects on available water resources, and

- to attain improved water management practices that would minimize water quality degradation due to human activities.

Water Resources in Regions of Water Scarcity (F4.02)

- to contribute and improve the quantitative assessment and protection of water resources in regions of water scarcity, in particular in arid and semi-arid areas, and

- to assist and. provide support to Member States for effective incorporation of isotope methods in routine practices for estimation and verification of hydrological field parameters for optimum management of scarce water resources.

The projects are being implemented by the Isotope Hydrology Section and the Agency's Laboratories.

Hydro-climatic Changes and Impact on Catchment and Surface Water Systems (F4.03)

- to assess and verify the application of isotope methodologies in studying processes in the atmosphere and hydrosphere related to natural and man-induced environmental changes,

- to permit improved prediction of their possible future impact on water resources, and

- to enhance the contribution of isotope applications for improved assessment of fluvial transport processes and minimize the adverse effects of such processes on soil and water resources.

Analytical Services and Quality Assurance (F4.04)

- to provide assistance and. support in the determination of the isotope and chemical composition of water and other environmental materials and to assure analytical quality.

Support to Technical Cooperation Programmes (F4.05)

- to provide technical support to the Agency's technical cooperation projects in Member States.

EDITORIAL

The current issue of Water & Environment News is focused on "Isotopes and Water Resources in Arid and Semi-arid Areas", a major component of the Isotope Hydrology Section's activities for about three decades. More than 30 percent of our current TC projects and part of our applied research programme activities are related to this field.

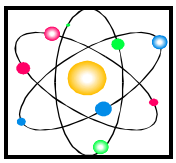
Some other activities related to this topic will also be included in this issue.

One theme is the newly approved Thematic Plan - Isotope Hydrology in Dam Safety and Sustainability. Through feedback from governments, the sustainability and safety of dams and reservoirs have been identified, as areas where the application of isotope hydrology can have a significant impact on socio-economic development, in terms of both cost-savings and safety for residents.

As will be announced in the staff change notice, Dr. PANG Zhonghe recently left the Agency and returned to his institute in China. He was in charge of designing of the original content and layout of the newsletter and was its editor for the first 6 issues. On the occasion of his departure from the Section, we would like to express our sincere appreciation to his efforts in making this newsletter a successful source of information four our readers world-wide.

I am pleased to inform that Dr. Cheikh GAYE, our new staff member, has taken over this task. I am sure he will do the job with the same dedication and effort.

Klaus Froehlich
Head, Isotope Hydrology Section



Thematic Plan - Isotope Hydrology in Dam Safety and Sustainability

As part of the efforts to improve the planning of the Agency's future Technical Co-operation programmes, a consultants meeting on Isotope Hydrology in Dam Safety was organised by the IAEA Department of Technical Co-operation at the Agency's Headquarters in Vienna, from 1999. The meeting was attended by international experts from Africa, Asia, Europe, Latin America, the World Bank, the International Commission on Large Dams (ICOLD), the private sector and IAEA. Its main objective was to help IAEA identify the end users for isotope technologies so that the technical co-operation can produce socio-economic impact through these end users. Priority areas of studies were identified and pilot countries for joint IAEA - World Bank assessments were proposed by the participants.

Development need, technical solution and nuclear technology

Dams and reservoirs are vital to the sustainability of a large part of the world's population for water supply, irrigation flood protection and hydropower generation. Their ability to function properly for a long time is crucial to the well being of these population segments. Very large investments are therefore necessary each year to increase the efficiency of dam and reservoir operations and thereby improve socio-economic development. Among other problems, funds are largely used for engineering and construction to mitigate three types of problems:

- leakage from reservoirs that flows under and around dams
- leakage through dams
- sediments that have deposited in the reservoir and depleted its storage capacity.

Isotope hydrology offers techniques for assisting with site selection, site investigations, watershed studies, dam and reservoir design, dam construction, dam and reservoir leakage investigations, sediment control and improving reservoir longevity. Most techniques play a catalytic role by supplementing conventional technology for solving dam management problems from planning through operations. However, three techniques were identified as having a primary role for investigating certain types of problems common to dam management:

- water "fingerprinting" through its isotopic composition to identify the origin and pathway of water in the hydrological cycle during all phases of a dam project, from planning through operations
- investigation of sedimentation in the reservoir resulting from erosion in the watershed during the first filling and subsequent operations for purposes of managing the sediment
- investigation of leakage pathways through and around the dam and through the reservoir floor during the first filling and subsequent operations, if leakage is observed.

Some isotope methods, while having the potential of providing new and unique technologies for addressing specific dam and reservoir

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problems, need further research and development. This includes isotope methods for tracing the origin of sediment within the watershed system. These methods must be validated before they can become accepted tools for dam management.

The TC approach for achieving project impact is to make sure that its investments in institutional capacity-building reach the end-user - the last link in the chain that connects the Agency counterpart with the problem holder. Since most of the end-users of analytical technology for dam safety and sustainability are commercial enterprises, interaction with the private sector is crucial to ensure the successful application of isotope techniques in this area. This presents a special challenge since the IAEA generally does not deal directly with the private sector. The main objective for the Agency's strategy must therefore be to bridge the gap between the technology providers and the problem-holders and to foster partnerships that will help achieve this objective.

Thematic planning

The implementation strategy consists of three interrelated components:

(1) Problem Identification - Joint Missions

This component aims to strengthen donor co-ordination, ensure that the Agency's activities are integrated with national plans and programmes and help generate a number of success stories which could be disseminated to a wider audience. The IAEA should initially participate in a number of World Bank missions where the conditions of adequate counterpart structure and relevant problems are expected to be met.

With the help of the World Bank, a list of countries has been selected which fulfill the criteria of Government commitment and existing dam problems.

(2) Expanded Informational Activities

An aggressive information campaign should be launched to sensitise the end users to the benefits of isotope hydrology in dam management. Direct partners in this exercise are NGOs - in particular ICOLD - and international organisations, in particular the World Bank. IAEA is preparing a brochure on isotope techniques in dam safety and sustainability, addressing questions that may be raised by the problem holders and end-users, as well as an up-dated technical document dedicated to dam-related applications of isotope hydrology.

(3) Validation of promising applications for future Technical Co-operation

Co-ordinated research programmes should be launched to develop and validate methods which were identified as particularly promising for applications in dam safety. One of the potentially most useful of them is the tracking of sediments that cause reservoirs to become progressively filled with silt.

The objective of these pro-active measures will be to build a demand for isotope methods in dam management which should, over time, lead to an increase in the requests for assistance in this area via the traditional channels.

Note : *Extract from the IAEA approved Thematic plan - Isotope Hydrology in Dam Safety and Sustainability*

Photo credit: B. Verhagen

A major dam in Africa stands empty due to a leakage of unknown origin. Tens of millions of dollars were spent pouring concrete at the base of the wall - a costly operation which did not solve the problem.

Presentation at Meetings by IHS Staff

Yuecel Yurtsever presented an invited key note paper entitled "Overview of Nuclear Science and Technology in Groundwater Assessment/Management and IAEA activities in the Gulf region" at the Fourth Gulf Water Conference held in Bahrain from 13 to 19 February 1999. The paper was also published in the proceedings of the Conference which was organised by the Water Science and Technology Association of the Gulf Countries and the Agency was a co-operation organisation in the meeting.

Around 125 participants from the countries in the Middle East region took part in the meeting and a total of 80 papers were presented in parallel sessions covering different aspects of water resources assessment, management and planning.

The Conference was also informed of the new regional TC project "Isotope Techniques for Improved Groundwater Utilisation - RAW/8/007" to be implemented during the 1999-2001 cycle with the main themes of assessment of recharge to aquifers / effectiveness of artificial recharge, and management of aquifers affected by salinity. It was recognised that these are problems of the highest priority in the region, and individual consultations and discussions were held with representatives from several countries on their possible participation in the regional project RAW/8/007.

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ISOTOPE HYDROLOGY FOR WATER RESOURCES IN ARID AND SEMI-ARID REGIONS

Scientific Scope

Lack of fresh water for different uses (domestic, agricultural and industrial) is presently hindering development in many parts of the world. Water scarcity is most acute in arid and semi-arid regions which cover almost one third of the Earth's land surface. Moreover, limited fresh water resources available in these regions are also threatened with deterioration in quality due to man-induced hydrological changes. The available water resources in arid regions are often restricted to groundwater. Surface flows are usually limited to flash floods due to short duration of high intensity rainfall events with very infrequent recurrences, which have little potential as a source of water.

Where availability of the renewable fresh water resources falls below 1000 m^3 per capita per year, chronic water scarcity is observed, and the lack of adequate water will be one of the main constraints on economic development and on human health and well-being. On the basis of future population projections, it is anticipated that the total population living in such water scarce regions will reach 2.8 - 3.3 billion by the year 2025. Countries observing water scarcity at the present and expected to be added into this category by 2025 are listed in Table 1 (Egelman & Leroy, 1993). As can be noted from the Table, the majority of the countries facing problems of water scarcity at the present and in the future are located in arid and semi-arid regions.

In addition to problems related to water quantity, deterioration of the quality of the available limited water resources in arid and semi-arid regions is also of great concern. In this regard, it is important that the scientific and technological advances made in the field of hydrology during the past few decades be fully integrated in water resources development and management practice.

Research and development efforts devoted to isotope applications in water sciences during the last decades have resulted in proven methodologies to be employed for a wide spectrum of applications in water resources development and management. The field often referred to as "Isotope Hydrology" is presently recognized as a scientific discipline.

Methods based on the use of naturally occurring isotopes are increasingly used in combination with other hydrological methods for water resources development and management. The specific role and application areas of different isotopes in arid and semi-arid zone hydrology are summarized in Table 2.

A substantial amount of basic data and results of applied field investigations have already been published on applications of different isotopes for the above cited hydrological purposes in arid and semi-arid regions.

IAEA Support for Arid Zone Hydrology in Member States

Technical Assistance on Water Resources Development projects

The technical assistance of IAEA to Member States in arid zone hydrology started in the early eighties in Africa, Latin America, West Asia and the Middle East. The main objectives of this assistance through the technical cooperation programme are to contribute to and improve the assessment and protection of water resources in regions of water scarcity, in particular in arid and semi-arid areas, and to assist Member States in incorporating isotope methods in routine practices for the determination of hydrological parameters for optimum utilization of scarce water resources.

Currently, the Section is involved in 12 operational technical cooperation projects in 25 Member States within the arid zone, four of which are regional projects in Africa, West Asia and the Arab- Peninsula (Fig. 1 and Table 3).

Support to Research Projects

The IAEA supplements field applications with research programmes on problems associated with water resources assessment and management in arid and semi-arid areas and where isotope techniques could provide for a better understanding of the rather complicated behavior of their aquifer systems. A Coordinated Research Programme (CRP) on "Isotope techniques in water resources investigations in arid and semi-arid regions" to support the research needs associated with water resources exploitation and management in arid regions involving Algeria, Egypt, France, Israel, the Russian Federation and the United Kingdom, was completed in 1998. The results of this will be published in the IAEA-TECDOC serie. Another CRP on "Isotope based assessment of groundwater renewal and related anthropogenic effects in water scarce regions" is being implemented from 1995-1999, with the participation of Austria, Bolivia, China, Egypt, India, Jordan, Mexico, Nigeria, Saudi Arabia, Senegal, South Africa, Syria, Tunisia and the United Kingdom. This CRP will bring an understanding on mechanisms of infiltration and diffuse evaporative discharge for selected aquifers in

Cont'nd on page 8

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Table 1. Countries experiencing water scarcity (less than 1000 m^3 of renewable water per person per year) in 1955, 1990 and 2025 (projected) [from Egelman & Le Roy, 1993, in Froehlich & Yurtsever, 1995]

Water scarce countries in 1955

Bahrain
Barbados
Djibouti
Jordan
Kuwait
Malta
Singapore

Countries added to scarcity category in 1990

Algeria
Burundi
Cape Verde
Israel
Kenya
Malawi
Qatar
Rwanda
Saudi Arabia
Somalia
Tunisia
United Arab Emirates
Yemen

Countries added to scarcity category by 2025 (under all UN population growth projections)

Comoros
Egypt
Ethiopia
Haiti
Islamic Republic of Iran
Lybian Arab Jamahiriya
Morocco
Oman
South Africa
Syrian Arab Republic

Table 2. Role and application areas of isotopes in arid and semi-arid zone hydrology (Froehlich & Yurtsever, 1995)

Recharge and discharge of groundwater resources
Diffuse infiltration
Saturated zone
- ^{3}H, freons, ^{36}Cl, ^{14}C (^{13}C) dating

Unsaturated zone
- ^{3}H profiles, bomb -^{36}Cl and Cl^- profiles
- ^{2}H, ^{18}O
- artificial tracers to study small scale processes

Bank infiltration and other sources
- ^{2}H, ^{18}O, ^{3}H

Exfiltration
- ^{2}H,^{18}O profiles in the unsaturated zone

Palaeohydrological applications
Definition of time scales
- ^{14}C(^{13}C), U/Th dating, ^{36}Cl

Palaeoconditions of aquifer replenishment
- ^{2}H, ^{18}O (deuterium excess), ^{14}C (^{13}C) dating, noble gases (recharge temperature)

Groundwater flow in large aquifers with various rock types
- $^{87}Rb/^{86}Sr$ etc..

Anthropogenic impact on water resources
Agricultural impact on groundwater
- ^{2}H, ^{18}O - surface water infiltration, irrigation effects, salinization, ^{15}N, ^{13}C, ^{34}S

Urban impact on groundwater
- ^{2}H, ^{18}O, ^{13}C, ^{34}S - leaking water distribution systems, waste disposal, industrial effluents
- artificial tracers (e.g. labelled hydrocarbons) leachate migration and degradation

Aquifer over-exploitation
- ^{2}H, ^{18}O (salinization), ^{3}H, ^{14}C monitoring

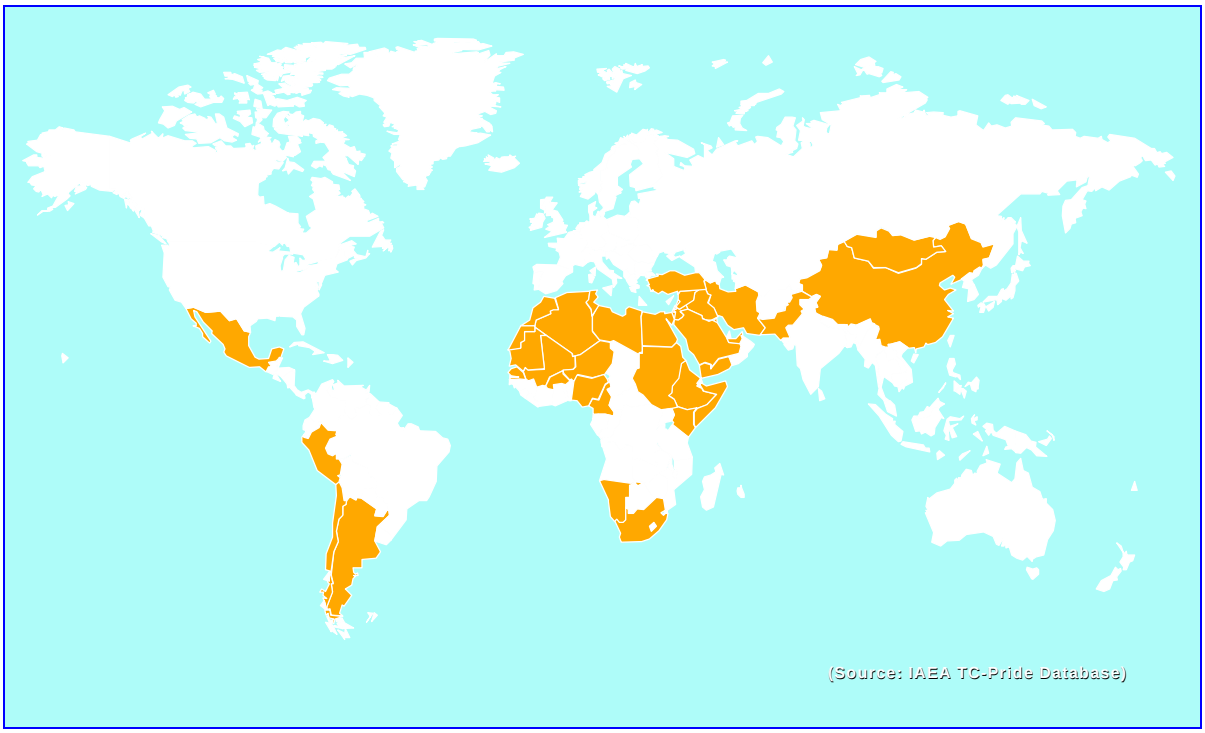

Figure 1 : Arid and semi-arid countries involved in IAEA technical cooperation projects (since 1976)

Table 3 : IAEA on-going Technical co-operation Projects related to arid and semi arid zone

Country	Project	Starting date
Ethiopia	Isotope techniques for water resources management	1999
Mali	Use of isotopes in groundwater assessment	1999
Mongolia	Isotope application in water resource management	1999
Morocco	Isotopes in the sustainable management of water resources	1999
Namibia	Improved monitoring of water flow distribution in Eastern	1997
Namibia	Caprivi	1999
Niger	Automatic tracer flow gauging stations in ephemeral rivers	1999
Pakistan	Assessment of the water resources in the Zinder region	1999
Uganda	Soil erosion and sedimentation studies	1997
Yemen	Isotopes in assessment and monitoring of groundwater	1999
Chile	Isotope hydrology investigation in the Sana'a region	1999
Algeria, Egypt,	Contamination of water resources in semi-arid zone	1995
Ethiopia, Mali, Morocco, Niger, Nigeria, Senegal, Sudan	Isotopes in groundwater resources development Regional Africa : RAF/8/022	1999
Kenya, Madagascar, Namibia, South Africa, Tanzania, Uganda, Zimbabwe	Sustainable development of groundwater resources Regional Africa : RAF/8/029	1995
Iran, Jordan, Kuwait, Lebanon, Saudi Arabia, Syrian Arab Republic., Turkey,	Isotope hydrology techniques in water resources management Regional West Asia	1999
United Arab Emirates, Iran, Iraq, Jordan, Kazakhstan, Syrian Arab Republic	Isotope applications for improved groundwater utilization Regional West Asia	

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the arid and semi-arid areas which will provide valuable input to management and protection of the resource as well as develop the methodology of hydrochemical and isotope profiles.

Manpower Development

Continuous efforts are being made to develop manpower capabilities in Member States within the arid and semi-arid regions to apply isotope techniques in water resources assessment and management through fellowships, workshops, seminars and training courses. Training has progressed from the basic aspects to advanced methods of geochemical modeling where isotopes are integrated. Mechanisms of sharing experience and expertise on arid and semi-arid zone hydrology are being developed through collaborative efforts within regional projects such as RAF/8/012 for Member States in the Sahel (1987-1992).

Establishment of Laboratories

Laboratories for isotope measurements as well as for chemical analyses were established or up-graded in several Member States, inter alia Algeria, Egypt, Iran, Jordan, Morocco, Niger, Pakistan, South Africa, Syrian Arab Republic, … under the different IAEA projects dealing with arid zone hydrology. Emphasis is put on quality assurance for chemical and isotopic analyses in the daily laboratory practice through inter-comparison exercises, both at the regional and inter-regional levels.

Dissemination of Information

The Proceedings of an Advisory Meeting Group on the Application of Isotope Techniques on Arid Zone Hydrology held in Vienna in 1978 were published in 1980 by the Agency. This publication showed that the most significant results achieved by using isotope techniques in arid zone hydrology concern the occurrence and mechanisms of modern and past recharge and the evidence of interconnections between aquifers. The Agency has joined the UNESCO effort in the International Hydrological Programme and has contributed to the preparation and publication in 1989 of a "Critical Review on the use of environmental isotope techniques in arid zone hydrology" in the UNESCO Technical Documents in Hydrology. Two TECDOCs were published by the Agency on isotope field applications for groundwater studies in the Sahel and in the Middle East, in 1993 and 1996, which provide an in-depth analysis of isotope results in the aquifer systems studied as well as a basis for more effective planning for future isotope investigations in these two regions. A third TECDOC presenting the results of the CRP on the use of isotope techniques in water resources investigations in arid and semi-arid regions, which was completed in 1998, is being prepared by the Agency.

Future Outlook

For several years, isotope techniques have being used in Member States in the arid and semi-arid regions to solve problems dealing with the availability and the quality of their water resources, but there is often lack of baseline data and no actual integration of isotopic tools in groundwater management. That is why it is necessary to undertake studies using isotope techniques to solve practical issues for the management in close partnership with water resources planners.

The areas in which there is still a strong need for the application of isotope techniques are :

- the assessment of recharge and discharge (in arid zones, the amount of recharge actually reaching the saturated zone is very limited and in most cases the unconfined aquifers are losing water by evaporation);

- the distinction between the rarely present recharged water resources from those which are inherited from previous humid climatic periods (mining groundwaters);

- the assessment of the efficiency of water harvesting through artificial recharge schemes, and

- the anthropogenic impacts of agricultural, industrial and urban activities on water resources.

The increase of benchmark case studies in the framework of regional projects and the wide popularization of their results through training and mass media communication.

Cheikh B. Gaye/IAEA

References

Froehlich K. & Yurtesever Y. (1995). Application of Tracers in Arid Zone Hydrology. IAHS Publ. n. 232, 3-10

Left : A site in North Senegal for Arid zone hydrology investigation using profiles in the unsturated zone (Photo credit : M. Daouad, UCAD, Senegal).

Right : Water scarce area in Namibia desert (Namib) also subject of IAEA's activities (Photo credit : K. Froelich)

INTERNATIONAL SYMPOSIUM ON ISOTOPE TECHNIQUES IN WATER RESOURCES DEVELOPMENT AND MANAGEMENT

The International Symposium on "Isotope Techniques in Water Resources Development and Management" organised, by the International Atomic Energy Agency in co-operation with UNESCO, WMO and International Association of Hydrological Sciences was held in IAEA Headquarters, Vienna last 10-14 May, 1999. The Symposium was attended by 207 participants from 65 Member States and representatives of international organisations.

Photo credit:C.Devia-Torres

Participants of the International Symposium on Isotope Techniques in Water Resources Developement and Management

The Symposium provided an international forum for assessing the status and recent advances in isotope applications to water resources through three invited keynote speeches, 46 oral presentations and 98 poster presentations, on the following main themes:

- processes at the interface between the atmosphere and the hydrosphere;
- investigations in surface and groundwaters: their origin, dynamics, interrelations;
- problems and techniques to investigate sedimentation;
- water resources issues : pollution, sources and transport of contaminants, salinisation, water-rock interaction and processes in geothermal systems;
- isotope data interpretation and evaluation methodologies : modelling approaches.

A round table discussion during the Symposium reflected that isotope applications contribute substantially to various hydrological problems encountered in water resources assessment and management. It was subsequently stressed that isotopes should be an integral part of the routine investigations related to utilisation of water resources and protection to achieve the ultimate goal of sustainable development. In this regard, the envisaged future International Programme to be initiated by the Agency on "Isotopes in the Hydrological Cycle", to be implemented jointly by UNESCO and WMO, was strongly endorsed.

The proceedings of the Symposium will soon be published by the Agency as a CD-ROM.

For further information, please contact the Symposium's Scientific Secretary, Mr. Yuecel Yurtsever, Section of Isotope Hydrology, IAEA.

Groundwater problems studies in the Thar desert, India using isotope techniques

Introduction

The Thar desert extends from the western side of the Aravalli mountain ranges in India upto the limit of Indus valley in Pakistan. It covers 60% of the area of the Rajasthan state in the north western part of the country. With ~ 38% of the state's population with a density of 84 persons/km^2, this is one of the most populated desert regions of the world. The constantly increasing human and livestock population is putting tremendous pressure on the available natural resources (Figure 1).

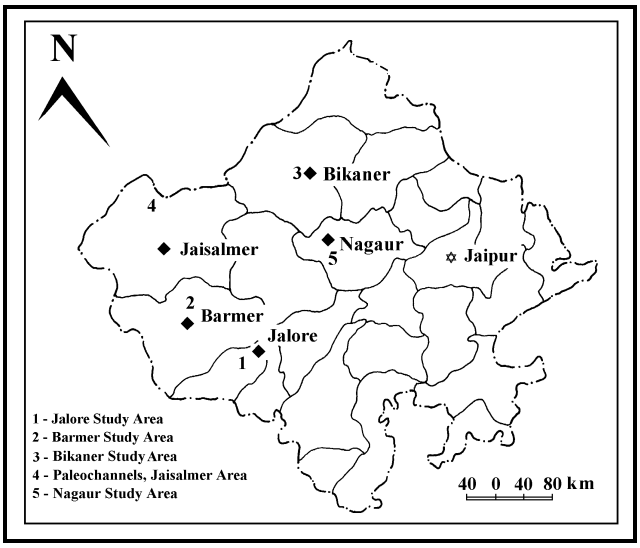

Figure 1 Location map of the study areas

The land is characterised by sand dunes with interdunal plains in the north, west and south, and alluvium in the central and eastern parts. Streams are very few, ephemeral in nature and confined mostly to the rocky parts of the desert, the most prominent being the Luni river in the southwest region. Precipitation is low and erratic with frequent droughts.

The main source of water in the area is groundwater. The region faces acute shortage of potable water and village women have to fetch water from many kms away to meet domestic requirements. In many places the groundwater is brackish or saline. Efforts are being made by the state groundwater department to study known groundwater resources and explore potential ones in the region.

In groundwater management, particularly in arid regions like western Rajasthan, it is important to know the presence of modern recharge and to estimate the recharge rate to avoid overexploitation of the groundwater resource. Isotopes can help to identify modern recharge and to estimate recharge rate to the aquifer. If modern recharge is absent, groundwater dating using radiocarbon could help to identify old groundwater or paleowaters. A number of isotope studies carried out in arid zones (particularly in the Sahara) have shown that the deep groundwater is generally very old. From these studies it was concluded that episodic large scale recharge corresponding to humid phases or pluvials occurred in these arid areas. The paper reviews our experiences on the application of isotope techniques in understanding groundwater recharge process in arid western Rajasthan.

Groundwater recharge process

The possible groundwater recharge process in arid areas like Rajasthan may be :

a) direct recharge of precipitation through the unsaturated zone
b) indirect recharge through river channels from flash floods or from irrigation canals etc.
c) paleoclimatic recharge during humid episodes in the past which was mentioned above.

Direct recharge of precipitation to the groundwater was studied in Jodhpur and Barmer districts of western Rajasthan using artificial ^{3}H tracer as HTO in the unsaturated zone (Shivanna et al 1994). The results showed that the tracer displacement and hence the groundwater was found to be negligible due to low rainfall (~ 200 to 300 mm) during the study periods of 1982-84 and 1990-92 respectively. Hence for arid areas the artificial tracer method which determines recharge on an annual basis for a short duration may not be useful and may be combined with other methods such as environmental ^{3}H, ^{36}Cl and chloride methods. In these methods results are derived from long term average of recharge. In central Sudan for example (mean annual precipitation = 180 mm) a net annual direct recharge of around 1 mm/a was estimated using the chloride method (Edmunds et al 1990). In a study being carried out under an IAEA/CRP on isotope based assessment of groundwater renewal and related anthropogenic effects, environmental chloride profiles in a site in Barmer district of western Rajasthan (Mean annual rainfall = 241 mm), showed a mean annual recharge of 14 mm. The recharge obtained by the chloride method is being compared with that of the tritium method. Unsaturated zone solute and isotope profile will also be used to provide a record of recharge history as interpreted for profiles from Cyprus and northern Senegal (Cook et al 1992).

In arid areas, indirect recharge through wadis (river channels) could be an important mechanism for ground-

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water recharge (Gonfiantini 1974, Darling 1987). Environmental isotopes (^{2}H, ^{18}O, ^{3}H) and ^{14}C were employed to identify the recharge process in the Jalore area of western Rajasthan (Navada et al 1993). The isotope results showed that most of the shallow groundwater near the Sukri river course, have $\delta^{2}H$ and $\delta^{18}O$ enriched compared to the shallow groundwater away from the river course and have ^{3}H values of 15-20 TU, showing that they are possibly recharged from river channels during flash floods. The deep groundwater (>100 m) near the river course also shows some component of recent recharge indicating probable interconnection between the shallow and deep aquifers. The other deep groundwaters away from the river course on the other hand have negligible ^{3}H and depleted $\delta^{2}H$ and $\delta^{18}O$, indicating recharge during more humid periods in the past.

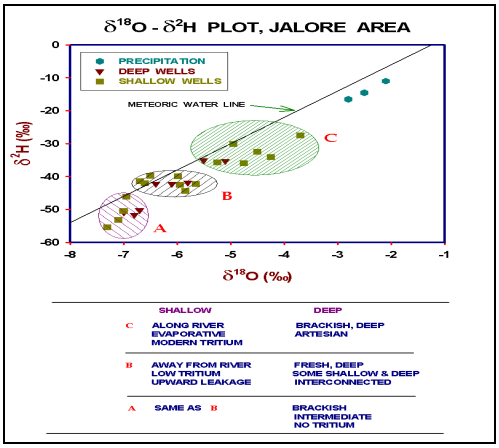

Figure 2 Deuterium and Oxygen-18 relationship of samples from Jalore area

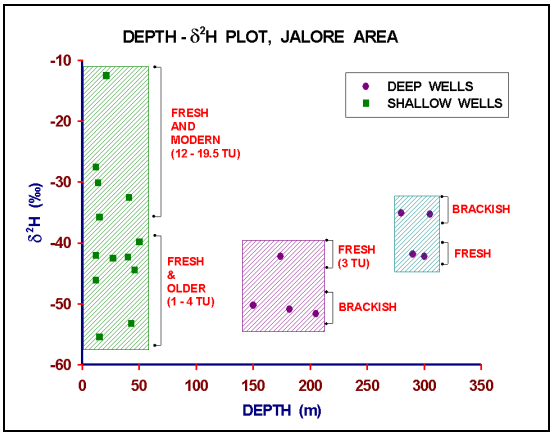

Figure 3 Depth versus Deuterium plot of samples from Jalore area

Buried courses of rivers (paleochannels) are important as they have good groundwater potential. Isotope studies were carried out along a buried river course in Jaisalmer district in western Rajasthan, which was supposed to belong to the legendary Saraswati river of Himalayan origin mentioned in many earlier literary works and known to have existed before 3000 years BP. The shallow groundwaters along the river course have negligible ^{3}H and low ^{14}C values of 54 to 70 pmc confirming that they are old waters.

An environmental isotope study in the Bhadka-Bheemda area in Barmer district in western Rajasthan (Navada et al 1996) showed that the deep groundwater (depth > 100 m) has depleted $\delta^{2}H$, $\delta^{18}O$ compared to the shallow groundwater and present day precipitation. They have negligible ^{3}H and ^{14}C model ages of these groundwaters range from 4000 to 9500 years BP. Hence they are paleowaters recharged in the past.

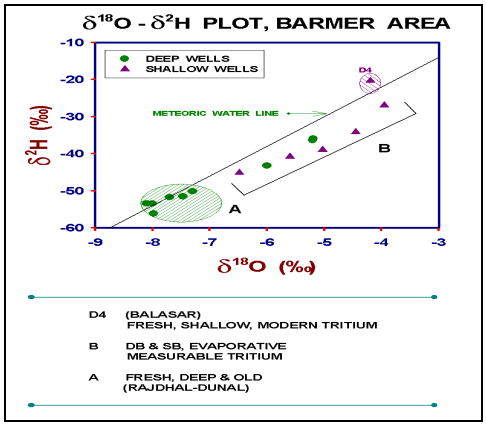

Figure 4 Deuterium and Oxygen-18 relationship of samples from Bhadka-Bemda area

Paleological studies have proposed the following dry and wet periods in Rajasthan (Bryson and Barreis 1967, Singh et al 1974).

10,000 - 6000 years BP	moderately humid, rain fall greater than present
5000 - 3000 years BP	humid period
3000 - 1100 years BP	low rainfall
1100 - Present	dry conditions

Hence the recharge to these groundwaters occurred during humid periods shown above.

Effect of over exploitation of groundwater

The increasing demand of water supply for various purposes has lead to heavy exploitation of groundwater resources in many parts of the world. This is particularly so in arid regions where limited water resources are being exploited with adverse effects of rapid lowering of water table and deterioration of water quality. For example in Bikaner town in Western Rajasthan the aquifers are being extensively used and the water levels have been declining. An isotope

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study (Navada et al 1996) showed that the shallow and deep wells have generally similar d^2H, $d^{18}O$ and negligible ^3H. The ^{14}C model ages of the deep wells vary from modern to 9500 years BP. Similar, d^2H, $d^{18}O$ of the shallow and deep groundwater and young groundwater encountered in some deep well samples indicates mixing of the shallow and deep zone waters due to heavy exploitation of groundwater in the area.

In an another example, in a limestone belt which extends from Bilara to Phalodi in Western Rajasthan, groundwaters are being heavily exploited for irrigation and domestic purposes. The isotope results (Nair et al 1993) show that modern recharge is possible in the southern part of the area through the Luni river which is ephemeral. In the central part the groundwaters have negligible ^3H, and ^{14}C indicates an age of ~ 2000 years BP. In Phalodi area in the north, the groundwater contains negligible ^3H and ^{14}C showing a maximum age of 4000 years indicating paleo recharge. Time series analysis of the tritium data of some of the wells showed a decreasing trend. This may be due to over- exploitation of groundwater in the central part leading to influx of older water from the north.

Thus, isotope techniques are useful in understanding groundwater recharge process in arid areas. Absence of modern recharge and over exploitation observed in some of the above studies stress the need for proper management of such scarce groundwater resources.

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Technical Review

GROUNDWATER RENEWAL IN WATER SCARCE REGIONS

The second Co-ordination Meeting of the Co-ordinated Research Project (CRP) on "Isotope -Based Assessment of Groundwater Renewal and Related Anthropogenic Effects in Water Scarce Regions" was held from 9-13 November 1998 in Sfax, Tunisia.

The CRP involves applied field research for study of the infiltration rate (natural recharge) and/ or diffuse evaporative discharge under natural conditions, through hydrochemical and isotope profiles at selected benchmark representative sites in arid and semi-arid regions. Institutions from fourteen countries (Austria, Bolivia, China, Egypt, India, Jordan, Mexico, Nigeria, Saudi Arabia, Senegal, South Africa, Syria, Tunisia and United Kingdom) are participating in this CRP.

The meeting reviewed the results and achievements of the work undertaken since the last co-ordination meeting held in Vienna on December 1997. In depth discussions were held on various related technical/ scientific issues concerning the results achieved, as well as further required work for successful completion of the CRP in 1999.

Significant progress was reported in most of the country projects. Spatial variability was an important question discussed at some depth. The long-term recharge rates provided by the unsaturated zone Cl profiles and supported by the ^3H, ^2H and ^{18}O data offered by far the best and most robust point source data for large areas of the semi-arid regions of the world. However these need to be integrated on a regional scale. Additional work required and tasks to be accomplished during the last year of the project have been identified.

It was agreed that the overall data and results be compiled in a TECDOC to be published by the Agency after the completion of the CRP.

The Responsible officer of this CRP is Y. Yurtserver.

CRP News

ISOTOPE TECHNIQUES FOR WATER RESOURCES IN THE ASIA AND PACIFIC REGION

Isotopic techniques are not yet widely used in practice to tackle major water resources issues in the Asia and Pacific region. This was the main conclusion of the Advisory Group Meeting (AGM) on " The Integration of Isotope Techniques in Water Resources Investigations in the Asia and Pacific Region", which was held in Kozhikode (India) during 2 to 5 November 1998. The meeting was attented by representatives of water resources agencies in India, Korea, Malaysia, Myanmar, Sri Lanka and Thailand.

The participants found that the principal constraints which prevent full integration of isotope with other hydrological techniques are, among others:

- Non-existent or minimal interaction between practising hydrogeologists and isotope scientists in most of the countries in the Region;
- Insufficient facilities for isotope analyses;
- A lack of sufficient training for field hydrologists in the use and application of isotope techniques;
- Absence of appropriate university curricula and post-graduate training courses in isotope hydro-logy.

From presentations on water resources development and management issues in their respective countries, three priority areas were identified, as common to most of the countries in the region, where the use of isotopes would be very helpful and would make a strong impact on the current practice of water resources development and management :

- Assessment of groundwater resources in different hydrogeological environments;
- Evaluation of the impact of artificial recharge on groundwater resources;
- Erosion and sedimentation in lakes, reservoirs and coastal areas.

The participants recommended that the Agency undertake the following activities to promote the integration of isotope techniques into hydrological practice in the region :

- Encourage better communication between practising hydrogeologists and isotope scientists, in the framework of the National IHP committees (International Hydrological Programme of UNESCO for example).
- Help to strengthen existing analytical facilities and their use at the regional level.
- Support and extend assistance for training of practising hydrogeologists in isotope hydrology.
- Develop a practical guide for the use of isotope techniques in hydrology, and a guidebook on the various requirements and procedures for sample collection for isotope analyses.
- Facilitate the inclusion of a course in isotope hydrology in university curricula, or at least introductory topics on isotope hydrology in courses on groundwater hydrology, hydrogeology, geophysics, water quality, etc.

ISOTOPES FOR IMPROVED DRINKING WATER RESOURCES MANAGEMENT

A workshop aimed at assessing the factors affecting implementation of the project RAS/8/084, "Isotope Applications for Improved Drinking Water Resources Management" was held on 3 and 4 December 1998, in conjunction with the UNDP/IAEA/RCA Regional Field Training Course on "Application of Isotope and Chemical Techniques to Groundwater Problems", held at the Bhaba Atomic Research Centre, Mumbai, India, from 30 November to 4 December 1998.

The objectives and implementation programme of the project were presented by Jane Gerardo-Abaya, from IAEA. The national hydrological problems for each participating country to be included in the field investigation under the project were discussed with counterparts from China, India, Indonesia, Malaysia, Philippines, South Korea, Sri Lanka, Thailand and Vietnam and with experts from Australia, New Zealand and Philippines.

The workshop came to the conclusion that the main factors affecting the implementation of RAS/8/084 are :

- Need to define the hydrological problem to be solved bearing in mind the required end result which is to provide access to drinking water supply in the area
- Need to pursue the active involvement of the water resource agency which is the end user of the results of the project.
- Need to identify suitable counterparts to implement field investigations and generate an adequate well interpreted conceptual hydrogeochemical model of the study area.
- Need to assess the quality of analytical results of water chemistry.

The workshop also admitted that differences of experience exist among the concerned countries. Some countries have limited experience in the application of isotopes, while others require assistance to attract the collaboration of end users. These issues would require the direct involvement of the Agency through technical missions to Member States.
To the Agency the participants recommended :

- to carry out technical missions in the participating countries to address the issues of participation of end users, definition of the problem and formulation of work plan for the overall field work required including isotope investigations.
- to organise an inter-laboratory comparison for chemical results during the second quarter of 1999.

SUSTAINABLE DEVELOPMENT OF GROUNDWATER RESOURCES : A NEW REGIONAL MODEL PROJECT FOR AFRICA

The first coordination meeting of the regional model project RAF/8/029 for Southern and Eastern Africa was held in Vienna, Austria, from 22 to 26 February 1999. The meeting was attended by representatives from six participating countries.

The main objective of the meeting was to prepare refined national project proposals; budgets and schedules for the national efforts, within the framework of the project funding as approved by the Board of Governors (BoD); and to develop work plans for the first year of project implementation detailing, support from IAEA and necessary national inputs.

A presentation made by representatives of IAEA on the scope and budget for the model project RAF/8/029, as approved by the BoD, was followed by discussions on strategies for integrating the model project with national priorities and water sector efforts under way through other channels so as to
everage IAEA assistance. The national hydrological and hydrogeological problems for each participant country to be included in the field investigation under the model project were discussed with counterparts representing : Madagascar, Namibia, South Africa, Tanzania, Uganda and Zimbabwe.

The effectiveness and the efficiency of the implementation of the model project will depend on the following :

early planning of isotope investigations,

wider constituencies, in order to direct efforts to end users,

more direct contact between IAEA and the water sector,

Need for better communication between project partners.

The most significant conclusions of the meeting were:

- Equipment provided under the project will include a liquid scintillation apparatus for the Schonland Research Center (SRC) who will serve as regional laboratory and field equipment/supplie to support national project activities. The IAEA will also pursue outside resources to fully upgrade the SRC labs in the best interests of the regional program.

- A US contribution of $100,000 has been allocated to the project for 1999 and planned additional contributions of $100,000 will be made in 2000 and 2001.

- The LSA in Tanzania is now in operation. In 1999 it will primarily be tasked with analyses for the national project, but should be available for regional support in the future.

- Channels of communication will be developed by the IAEA to facilitate communications between project partners.

- A manual for isotope applications in water resources assessment will be developed under the project. One possibility is to produce the manual as an IAEA TECDOC in the second or third year of the project with the help of project consultants. Planning and initial efforts for this manual should get under way as soon as possible to ensure its completion within the scope of the project.

The responsible technical officer is Cheikh B. Gaye.

TRAINING COURSE ON CHEMICAL MODELLING

A regional training course on Geochemical and Isotope Modelling was organised within the framework of the ongoing regional TC project RAF/8/022 and held from 28 November to 9 December at the Research Institute for Groundwater, National Water Research Centre, Cairo, Egypt. The Course was attended by 29 participants from the 9 countries involved in the regional project, namely Algeria, Egypt, Ethiopia, Mali, Morocco, Niger, Nigeria, Senegal and Sudan.

The course was organised in response to the strong requests made by the countries participating in the RAF/8/022. It was recognised that the development and management of groundwater resources generally is optimised by using computer models of aquifer systems. These hydrologic models such as MODFLOW commonly used for aquifers in porous media, provide an understanding of the aquifer systems under natural conditions and under various levels of resource exploitation. But they require information on the geology and groundwater hydrology, which is developed through extensive geologic and hydrologic investigations in the field as well as in the laboratory. There exists, however, a great amount of variability in the geologic and hydrologic properties which makes the task of hydrologic modelling quite difficult. Isotope hydrology techniques provide integrated information on the source and quantification of recharge and the results of hydrologic processes controlling the groundwater system. The results of isotop hydrology investigations are most effectively used to estimate parameters for use in hydrologic models and to verify the results of hydrologic models. Depending upon the nature and amount of isotope data collected in a given study, geochemical models may be used to derive from the isotopic data, hydrologic parameters and constraints that can be used in hydrologic modelling.

The training course in Cairo, therefore, focused on the hands-on use of geochemical models SOLMINEQ.88 and NETPATH. These models are commonly used for studies related to groundwater systems. The course emphasised a brief theoretical introduction followed by actual use of the modelling codes by the participants. The participants were encouraged to use the models with their own data derived from the RAF project.

Judging by the interest shown by the participants in the actual use of the models, including that with their own data, the course was quite successful in building capacities in the use of geochemical models. The feedback received from the participants indicates that the course was quite successful in meeting its objectives. It is recommended that similar courses should be conducted in the future at the country level in order to disseminate the information more widely.

ISOHIS DATA BASE

The Isotope Hydrology Section is establishing an information system to gather, store and disseminate chemical, isotopic and geographical data from isotope-hydrological sites around the world. This system is referred to as the Isotope Hydrology Information System (ISOHIS).

The objectives of ISOHIS are:

- to facilitate data communication between counterparts of TC projects and the IAEA.
- to save, store and facilitate easy access to data gathered during more than 30 years of IAEA isotope hydrology studies.
- to integrate the highest possible proportion of existing and new, high quality data in a common database.
- to provide data to IAEA RC and TC projects as well as other national and international projects.
- to assist in developing local and regional databases
- to give recognition to and highlight the role of the data providers.

The system will consist of three components:

- software for entering records, to be used by counterparts in Member States;
- software for entering and verifying records, to be used by the Isotope Hydrology Section; and
- a Web site for querying the database, to be used by registered users from the general public.

The database will contain the following:

- summary information about the project;
- basic information about the samples taken;
- data on the concentrations of the major and minor ions, trace constituents, isotopes, dissolved gases measured in water, and relevant hydrological, hydrogeological, geographical data collected in the field;

The software for entering records and the user manual can be downloaded from *ftp://ftp.iaea.org/dist/isohis/*. The file name is : ihscp10.exe . This is a self-extracting file.

The Web site will be open to the General Public soon.

ISOTOPE HYDROLOGY CALENDAR

1999

IAEA MEETINGS AND TRAINING

September

RCM on Isotope techniques for the assessment of slow moving deep groundwater and their potential application for the assessment of waste diposal.
Bern, Switzerland

AGM - Prepare a technical document on the state of the art in GC/CF-IRMS
Vienna, Austria

October

CM on IAEA/UNESCO Teaching material in Isotope Hydrology.

4-8, **RCM** on "Isotope Techniques to Study Soil Erosion and Sedimentation in Lakes and Reservoirs, Phase II"
Barcelona, Spain

RCM on **"**Isotope-based Assessment of Groundwater Resources"
Vienna, Austria

November

RCM on "Isotope response to dynamic changes due to long-term exploitation in groundwater systems"

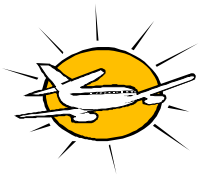
RCM on "Radionuclide Transport Dynamics in Freshwater Resources".

Final assessment meeting of the TC project on "Geothermal Energy Resources and Environment Management", Indonesia (RAS/8/075)

IAEA Meeting Categories

AGM: Advisory Group Meeting
RCM: Research Co-ordination Meeting
CS: Consultants Service
CM: Consultants Meeting
SYM: International Symposium

Staff Changes in the Isotope Hydrology Section



Departure:

working for two years in the Isotope Hydrology Section. As a temporary assistant professional in isotope geochemistry, his activities were mainly related to the efforts of the Section to enhance the transfer of know-how and technology in isotope hydrology to developing member states. He was in charge of "Water & Environment News" and was involved in activities related to the GNIP database and ISOHIS.

Dr. Pang has resumed his previous job in China as a research scientist in isotope hydrology.

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Dr. PANG Zhonghe left the Agency in early April after

ERRATA

The cover photo of issue No 6 was erroneously captioned. It is actually well AH-6 in Ahuachapan Geothermal field, El Salvador. We apologize for this error.

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