WATER PARTNERSHIPS

IAEA REGIONAL PROJECTS FOR AFRICA TAP EXPERTISE

BY ALI BOUSSAHA AND ROYAL F. KASTENS

Freshwater is a precious and limited resource. Only about 0.007% of all the earth's water is accessible for human use. If the earth's total water reserves were compared to one gallon, freshwater (including snow and ice) would make up less than half a cup (about 3%), and readily accessible freshwater would be just about two drops!

Competition for those drops is increasing exponentially: Since 1900, demand for freshwater in the world has increased by a factor exceeding six -- more than double the rate of population growth. By present estimates, some 400 million people currently live in areas with severe water shortages. In fifty years, four billion people may experience these conditions. Each year some 90 million people are added to the global population, and nearly every country will experience a *per capita* reduction of available water resources during the next three decades.

Africa may face the most daunting challenge of any region. Its annual rate of population growth already is high, and expectations are that growth will stay above 2% for the foreseeable future. The situation for the continent is exacerbated by prolonged droughts in arid and semi-arid zones, conjugated to high population pressures, particularly in urban areas, and a rapidly growing competition for water in the agriculture and industrial sectors. Most African urban centers have difficulty in meeting the water supply and sanitation requirements of their present populations, and they face challenging prospects for meeting the human health, social and economic, and environmental impacts of the future.

Issues of water scarcity are on the top of governmental agendas. The efforts of the IAEA's African Member States to address these issues rely upon increasingly complex requirements for analytical tools, technologies and institutional capacities. National programmes in water resources management are receiving growing attention and a large number of bilateral and multilateral development

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Photo: Through IAEA-supported studies, hydrologists in Ethiopia are scientifically mapping underground water resources. *(Credit: Kinley/IAEA)*

partners are actively involved in providing technical and financial support.

Over the past years, agencies in the United Nations system, the donor community and non-governmental organizations (NGOs) have played a key role as policy advocates and technical advisors. Among the sources of capital investment, the World Bank has been the most influential. It has financed numerous completed and ongoing water projects at a total cost of almost $60 billion between 1961 and 1995.

Yet major challenges remain. The capacity of governments to address problems in the water sector often is limited by the lack of appropriate policy and analytical frameworks, including regulatory aspects of water management and service delivery. This results in a fragmentation of efforts and inefficient formulation and implementation of water resource assessment and management programmes. Even a cursory review of the policy papers, country assessments, and analytical compilations prepared by governments and the international community reveals that data management systems for national water resources are generally inadequate throughout the region.

The lack of reliable information has obvious implications, and it especially constitutes a major constraint to implementing effective national strategies and programmes for the management of water resources.

African countries, with the active cooperation of their development partners, are paying more and more attention to strengthening national infrastructures for water resources management. This encompasses capacity building and upgrading of national skills in planning, formulation and implementation of development projects in the water sector. The ongoing efforts include, as part of the national technical capacity building, the integration of appropriate tools that strengthen further the availability of data for supporting sound decision-making.

IAEA TECHNICAL COOPERATION

An important aspect of strengthening national capacity for water resources management is the requirement to more fully understand human interaction and natural processes in the hydrologic cycle at many levels. For instance, surface water remains the primary source of freshwater for two-thirds of the world's population, but groundwater is increasingly important for rural populations and as the main source of irrigation to meet national food security requirements. Furthermore, groundwater is being heavily overused in many regions where water is being extracted faster than it can be replenished. Some groundwater called "paleowater" cannot be replenished as it was deposited in earlier epochs.

Pumping too much groundwater has dropped water levels by tens of meters in some areas, making it increasingly difficult and expensive to maintain access to water, and or influencing the quality of these sources by introducing interaction with natural and man made pollutants. Over-pumping can also have a serious effect on the base flow of rivers, resulting in negative consequences for fisheries and ecosystems. The problem of over-exploitation of groundwater is expected to increase over the next 30 years.

With this expectation comes the need for accurate and timely information. Data is required about age, recharge rates and locations of recharge, mixing between water bodies, and sources of salinization, especially in arid and semi-arid zones, and other parameters that influence quantity, quality and sustainability.

Nuclear & Related Applications. Applications of nuclear techniques in the field of hydrology constitute important, and sometimes unique tools for obtaining critical information needed for water resources management. In most cases, isotope hydrology methodologies provide a qualitative definition or solution of the hydrological problem while in certain circumstances, quantification of hydrological parameters are enabled only by the application of these methodologies. Such information is essential for determining the long-term productive capacity of an aquifer, protecting vulnerable recharge areas from pollution, or limiting saltwater intrusion. Isotopes also provide useful data for constraining and validating groundwater models used for water management. For many development issues, isotopes can be nearly "indispensable". *(See box, page 20.)*

There are significant technological and economic benefits of using isotope hydrology techniques, especially when they are used as an integral part of hydrologic practices in the water sector. To realize these benefits, the water management sector requires the ability to make precise measurements of isotope concentrations, and the trained expertise to apply, further develop, or adapt available technology to local conditions.

As in other fields, technical cooperation in isotope hydrology is well defined in terms of the Agency's mandate and technical competence. For over 40 years, the Agency's programme in isotope hydrology has built national capacities to gather, interpret, and apply isotopic data for hydrologic applications. In recognition of the great potential of isotope hydrology, particularly in the context of Africa, the IAEA's Board of Governors endorsed in 1994 an integrated regional approach to maximize the benefits of Agency-assisted technology transfer activities in the water sector. Since 1995, concerted and systematic efforts have been sustained to effectively integrate isotope hydrology techniques in hydrologic practices in Member States. The inception of the IAEA's new Technical Cooperation Strategy in 1997 has created the suitable framework and provided the modalities for further consolidating the initiatives taken by Member States and the Agency to increase the impact of isotope hydrology projects in Africa.

CASE STUDY: REGIONAL AFRICA PROJECTS

There is increasing awareness among countries of the important role and potential contribution of isotope hydrology in addressing practical problems pertaining to water resources management. This has prompted several African Member States to seek the Agency's technical assistance for the development of an appropriate approach for integrating isotope techniques with national water resources management programmes.

Regional Model Project on Isotopes in Groundwater Resources Development. Responding to these requests, the Agency developed a regional project for technical cooperation related to major government and/or donor-supported water sector investments. Started in 1995, this project opened with a first phase (1995-97) involving four countries (Egypt, Ethiopia, Morocco and Senegal). The project was extended in 1997 to include five further countries (Algeria, Mali, Niger, Nigeria and Sudan) in its second phase.

The objectives of this undertaking were to (1) demonstrate the practical short-term impact of isotope hydrology techniques, and (2) contribute to Member States' long-term capacity building efforts for better water resources management.

An important goal was to reach the end-users with a view to maximize the benefits of technical cooperation. In designing and formulating operational activities, particular attention was given to the national institutional and operational framework and special efforts were made to establish linkages with other donor-supported programmes in individual countries.

Extensive consultations with Member States have been conducted during the

COUNTRIES PARTICIPATING IN IAEA REGIONAL WATER PROJECTS IN AFRICA

DEVELOPMENT ISSUES & WATER RESOURCES

For understanding development issues inherent in the management of water resources, isotope methodologies provide valuable information and data. Specific applications include:

Improving Water Resources Assessment

■ *Natural Recharge/Discharge -- as an input to estimates of water balance.* Applications determine the sources and area of recharge (essential for water balance and water availability); determine processes of recharge (how recharge takes place and its dynamics); estimate the rate of recharge; and estimate the rate of diffused discharge.

■ *Fossil/Paleowaters -- commonly encountered in arid zones.* Applications map occurrence of water particularly for transboundary aquifers; improve assessment of the hydraulic relation to adjacent surface/groundwater bodies; estimate resources.

■ *Verification of Water Balance through Groundwater Flow Modelling.* Isotope applications can provide a confirmation of the observations obtained from traditional hydrological investigations.

Groundwater Management Issues

■ *Groundwater Pollution.* Applications identify some specific sources and processes; establish pollutant transport patterns and dynamics; validate/calibrate pollutant transport models; assess aquifer vulnerability to pollution in support of decision-making.

■ *Exploitation and Over-exploitation of Groundwater Resources.* Applications make it possible to assess the source and process of groundwater salinization; assess induced adverse effects due to exploitation.

■ *Artificial Recharge of Groundwater.* Applications assess the effectiveness of different recharge schemes; identify the most suitable sites of recharge, considering hydrogeological conditions.

■ *Impact of Reusing Waste Water on Groundwater Resources.*

formulation process. These consultations were intended to ensure the active participation and commitment of national water authorities in the isotope hydrology projects. Inclusion of national water authorities or end-users in the technical cooperation projects at an early stage was intended to develop strong functional relationships with national atomic energy authorities, relevant technical institutes, and university-based hydrology departments.

Project activities in all countries were focused on development issues of major concern. Some specific examples of field studies and activities in selected countries are illustrative of work being done.

■ *Egypt.* Egypt is facing a crucial shortage of freshwater resources. The completion of the High Aswan Dam and regulation by the government of water releases downstream the Aswan Barrage helped in saving water discharges to the sea. Accordingly, more water was made available for the reclamation of new lands on the fringes of the Nile flood plain. However, due to the limited available surface water, new land reclamation projects have to depend totally on locally pumped groundwater. Two such land reclamation schemes in Wadi Qena and Esna were selected for the isotope hydrology project. These two sites cover an area of 4500 km^2 where aquifers extend down to about 200 meters. The sustainability of water supply is highly dependent on the continued availability of groundwater, both in quality and quantity. Results of previous studies indicated a considerable interaction between groundwater in different aquifers.

Based on the isotope hydrology investigations, distinct isotopic features were found between groundwater in the Nile aquifer system and the adjacent Nubian sandstone aquifer. The relationship between recent Nile water, old Nile water (pre-Aswan dam), and their contributions to the replenishment of the aquifers were also defined.

In addition to recharge from the present-day Nile water, paleowater from the Nubian sandstone aquifer was estimated to be contributing around 30% of the total input sources to the aquifers exploited for land reclamation schemes. The evidence for groundwater replenishment identified by this field study is likely to benefit efforts for the sustainable development of water resources and may also lead to other land reclamation projects along the desert fringes.

■ *Senegal.* In Senegal, the potential of groundwater resources in the Cape Verde

Peninsula region was re-evaluated. This region includes the capital city of Dakar, which suffers a severe water shortage. The isotopic investigations provided critical data for the sustainable management of the aquifer systems used for supplying drinking water to the city.

■ *Morocco.* Two regions in the water scarce areas of south-central Morocco (Tafilalet and Guelmin) were selected for the regional project. Isotopic studies provided a new understanding of the aquifer systems in both areas. In the Tafilalet area, it was shown that one of the aquifers was being exploited under mining conditions and it was decided to close off five artesian wells. In the Guelmin area, the feasibility for artificial recharge of the Seyyad aquifer using surface water was established and a suitable site for this was identified on the basis of the isotope study.

■ *Ethiopia.* Assessment of groundwater replenishment was targeted in the Moyale region of southern Ethiopia. Recurrent droughts in this region, with a population of about three million, create a chronic shortage of water for drinking and irrigation. Results of the isotope hydrology investigations show a widespread recharge of the groundwater through rainfall, but at a much lower rate compared to previous estimates. The study also highlighted the sustainable potential of two sedimentary and fracturated rock aquifers in the Moyale region which can potentially be used for rural water supply.

Regional Model Project on Sustainable Development of Groundwater Resources. Following the success of the 1995 regional project and lessons learned with respect to specific project formulation and implementation issues, a second regional Model Project was initiated in 1999 for southern and eastern Africa. This project involves seven countries (Kenya, Madagascar, Namibia, South Africa, Tanzania, Uganda and Zimbabwe). It was formulated as a series of parallel national sub-projects focused on field activities at the country level. The Model Project's regional component was designed to promote cooperation and the exchange of information and experience among participating countries, and to strengthen further the regional capacity for provision of isotope applications. Its overall objective is is address practical problems in the development and management of groundwater resources in fractured hard rock aquifers and alluvial aquifer systems where the issues of salinization, pollution, and over-exploitation are of major concern. Selected national activities are highlighted below.

■ *Madagascar.* In Madagascar, the specific objectives of the IAEA's assistance are to establish groundwater dynamics and to evaluate the nature and origin of groundwater quality problems in the southern part of the country. These activities are complementary to and are integrated into the larger water resources development and management activities of national and international agencies, including the United Nations Childrens' Fund (UNICEF), the World Bank, United Nations Development Programme (UNDP), and the Japanese International Cooperation Agency. This project is being implemented jointly by the water resource authority (Directorate for Water Exploitation) and a nuclear science institute (National Institute of Science and Nuclear Techniques). In addition, a national project steering committee including all stakeholders of the water sector is being organized.

■ *South Africa.* The South African national sub-project focuses on the assessment of groundwater resources available from the Taaibosch fault zone in the Northern Province. A preliminary design for a water supply system for several villages having a total population of approximately 60,000 residents has been developed. Implementation depends on verification that the local groundwater resources are adequate to meet the projected demand over the long term. The project team is managed through the Department of Water and Forestry (DWAF) and the management regards the Taaibosch project as a pilot study for assessments of groundwater regionally and across South Africa.

A large part of project implementation is handled via contract with a private consulting company. Analytical services and data interpretation expertise are being provided by a school and nuclear research centre, which also is supporting (as a regional facility) activities in the other countries participating in the

SUSTAINING ISOTOPE HYDROLOGY CAPABILITIES IN AFRICA

The IAEA is developing the framework for a strategic plan to consolidate and sustain the capabilities of African countries to benefit from applications of isotope hydrology. The overriding development objective is to promote integrated and sustainable water resources management.

Major components of the strategic plan are to:

- Reinforce institutional capacity and the competency of human resources.
- Promote stakeholder involvement, and outreach with the private sector.
- Foster regional cooperation and collaboration.
- Support medium- to long-term national programmes.
- Strengthen data and information systems.

regional Model Project. The DWAF is working with the Water Research Commission to co-ordinate a project steering committee and to include representatives from other organizations within the South African government active in the water sector.

■ *Zimbabwe*. In Zimbabwe, groundwater resources of an area of about 4000 km^2 are being characterized in the Save alluvial deposits of the southern part of the country. The Save river flows south into Mozambique. A conceptual model for the groundwater system has been established and is being used to guide field activities.

The national sub-projects included in this regional undertaking are part of high priority government programmes. In many cases, these programmes are funded by bilateral and multilateral donors and the assistance of the Agency is sought to enhance ongoing studies where firm conclusions cannot be reached with conventional hydrogeological techniques. Recent changes in water law and resource allocation in some of countries are also stimulating increased technical understanding of the available water supplies so that equitable and efficient distribution can be accomplished.

FUTURE CHALLENGES

While the Agency's programme in Isotope Hydrology has played a critical role in fostering conceptual developments and practical applications in this field, significant challenges remain in integrating the isotope methodologies in the water sector. Toward this end, the IAEA has identified the components of a strategy to sustain the capabilities of the Member States for using isotope hydrology in water resources management. *(See box, this page.)*

Isotope hydrology may provide generic improvements in natural resource management, but first it must become recognized as a key tool to improve decision-making for a particular set of problems. Often, the Agency's counterparts in isotope hydrology laboratories are not aware of the data needs and requirements of the engineering firms that water authorities contract to investigate and solve problems of water scarcity and quality.

The strategy being followed in the Agency's Technical Cooperation Programme, therefore, is to focus on projects that target specific solutions to a developmental problem and build partnerships with national and international stakeholders. Partnerships with the World Bank and other international financial institutes are singularly important because programmes funded by external capital assistance usually reflect both high priority and strong commitment from national authorities.

From experience, isotope techniques provide technical data and insight that can improve decision making by the major stakeholders in water management and protect national investments. However, the value of these contributions are not fully realized unless they respond directly to national water resource management objectives. Therefore, it is imperative that the IAEA's technical cooperation projects in isotope hydrology are programmed carefully to meet the data and knowledge requirements of national water authorities. Activities in the latest regional projects in southern and eastern Africa reflect these efforts. A potential third generation effort for isotope hydrology will aim to link the capacities developed in the northern, southern, and eastern African regions with those emerging in West Africa. ❐