H_2O know-how

by Pradeep Aggarwal & Ali Boussaha

The IAEA spreads the science for harnessing the world's aquifers.

We know water is essential for life. Less known is that there may be enough freshwater for everyone — if the world's resources are well understood and responsibly managed.

Water is key to achieving socio-economic development. It is also a crucial element of poverty reduction efforts. In the Millennium Declaration, UN Member States resolved "to halve by the year 2015 the proportion of people who are unable to reach, or to afford, safe drinking water" and "to stop the unsustainable exploitation of water resources, by developing water management strategies at the regional, national and local levels, which promote both equitable access and adequate supplies."

The steady increase in global demand for freshwater, coupled with rapid industrial and agricultural development, is threatening the availability and quality of fresh water supplies. Today, a large part of the world population particularly in regions of water scarcity suffers from the lack of sufficient water supply. Mahatma Gandhi put it aptly more than 60 years ago when he said "there is enough water for human need, but not enough for human greed." According to the report of the UN Secretary General to the 2002 World Summit on Sustainable Development in Johannesburg, the global water crisis also is a crisis of governance.

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In Africa, for instance, inadequate access to water and sanitation is considered both a cause and consequence of poverty. Although there are abundant water resourceson the continent — about 17 large rivers and 160 lakes greater than 27 km^2 — most of these resources are located in the humid and sub-humid region around the equator. The surface runoff in Africa, on average, is much lower than average precipitation as a result of high evaporation and evapo-transpiration. This results in endemic drought in parts of the continent.

That is why for Africa groundwater — the underground ponds and lakes of aquifer systems — is a critical resource. It provides nearly two-thirds of all drinking water on the continent, and an even greater proportion to the peoples of northern Africa.

Similarly, water resources in South America approximate 3 million km^3 and only the equivalent of one-tenth of the total amount of water contributed by precipitation is used every year. The major problems these countries face are sustainable groundwater use and prevention of contamination of the available resources.

Groundwater Lifelines

Globally, groundwater represents about 90% of available freshwater resources, excluding the resources locked in polar ice. Nearly half of all freshwater used for drinking and irrigation worldwide is groundwater, linking the sustainability of groundwater resources to sustainable human development.

About 20% of irrigation worldwide, producing 40% of the food supply, is dependent upon groundwater. It is estimated that nearly 10% of global food production may be dependent upon irrigation water extracted from fossil or non-renewable aquifers. According to the Food and Agriculture Organization (FAO), the use of groundwater for irrigation over the last several decades probably has delayed the next food crisis.

There may be enough freshwater for everyone – if the world's resources are well understood and managed responsibly.

The Science of Isotope Hydrology

Despite the importance of groundwater for many societies, there is a lack of corresponding public concern about its protection, perhaps because the extent and availability of groundwater are not easily measured. The impact of the increasing degree of temporal and special climatic variability on the water resources also is an important consideration. Groundwater, to some extent, provides an opportunity to mitigate the impacts of climate change.

To develop sustainable management and policy frameworks, it is necessary to have sound hydrological information on the quality and quantity of water resources. Making such information available requires a substantial amount of time and financial resources, and generally cannot be achieved on the short time scale at which societal demands for water supply have to be met.

Nuclear and isotope methodologies provide powerful tools for hydrologists to rapidly assess and manage water resources at a vastly lower cost. Stable and radioactive environmental isotopes have now been used for more than four decades to study hydrological systems and have proved particularly useful for understanding groundwater systems.

Applications of isotopes in hydrology are based on the general concept of "tracing", in which either intentionally introduced isotopes or naturally occurring (environmental) isotopes are employed. Environmental isotopes (either radioactive or stable) have the distinct advantage over injected (artificial) tracers in that they facilitate the study of various hydrological processes on a much larger temporal and spatial scale through their natural distribution in a hydrological system. Thus, environmental isotope methodologies are unique in regional studies of water resources to obtain time and space integrated characteristics of groundwater systems. The use of artificial tracers generally is effective for site-specific, local applications.

The most frequently used environmental isotopes include those of the water molecule, hydrogen (namely deuterium, and tritium) and oxygen (oxygen-18 as well as carbon-13 and carbon-14) occurring in water as constituents of dissolved inorganic and organic carbon compounds. Deuterium, carbon-13 and oxygen-18 are stable isotopes of the respective elements whereas tritium and carbon-14 are radioactive isotopes.

Among the most important areas where isotopes are useful in groundwater applications include aquifer recharge and discharge processes, flow and interconnections between aquifers, and the sources, fate and transport of pollutants. In particular, under arid and semi-arid climatic conditions, isotope techniques constitute virtually the only approach for identification and quantification of groundwater recharge.

Pollution of shallow aquifers and of deeper aquifers due to the over-exploitation of shallow aquifers, by anthropogenic contaminants is one of the central problems in the management of water resources. Environmental isotopes can be used to trace the pathways and predict the spatial distribution and temporal changes in pollution patterns for assessing pollution migration scenarios and planning for aquifer remediation.

Global Maps of the World's Aquifers

The IAEA's Water Resources Programme aims to develop isotope techniques for water resources management and assist scientists to use these techniques correctly. A substantial part of the programme focuses on groundwater. Estimates of the world's groundwater resources are generally weak and reliable information on the proportion of renewable or non-renewable groundwater is sketchy. The IAEA, together with the United Nations Education and Cultural Organization (UNESCO) and International Association of Hydrologists (IAH), is working to improve the understanding of the global distribution and amounts of non-renewable or fossil groundwater. The investigations rely on the use of the labeling properties of isotope data collected from groundwater aquifers worldwide.

Most of the isotope data for global mapping of aquifers were collected over the last four decades as part of the IAEA's technical cooperation projects. These projects built substantial national and regional scientific capacity and infrastructure while helping to solve practical issues in surface water or groundwater management. At present, there are over 80 operational technical cooperation projects dealing with isotope hydrology in Africa, Asia, and Latin American regions, for an adjusted budget of about US$7 million.

Over the past years, the IAEA has been working very closely with its Member States to bring isotope hydrology into the mainstream of national and international water resource related programmes resulting in a wider use of isotope techniques for water resources management. In central Morocco, isotope results were used to improve a groundwater management model for the Tadla Plain, an important region for agriculture. In Yemen, isotope investigation of groundwater in the Sana'a Basin clearly identified the nature and source of recharge to the shallow groundwater


Michael Kenn

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systems. The work advanced understanding of the efficacy of artificial recharge measures, potentially leading to the use of a deeper, fossil aquifer for drinking purposes only.

Of late, the IAEA's technical cooperation projects in water resources have focused more sharply on partnerships with other development agencies. In Uganda, a project implemented in cooperation with the Austrian Development Cooperation led to the delineation of recharge areas of Chuho springs, near Kisoro town. These springs are being developed as the source of freshwater in the entire southwestern townships. The results of isotope investigations provided unique information critical for the sustainability of the new source of water.

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In Bangladesh, the IAEA worked in cooperation with the World Bank and the government to help develop sustainable alternatives for safe drinking water supplies. At present, a large part of domestic water supply is obtained from shallow tube wells tapping an aquifer that is contaminated with arsenic. Isotope investigations helped to determine the extent and renewability of a deeper aquifer.

Three technical cooperation projects related to aquifer systems shared by several countries in Africa were recently initiated in collaboration with the Global Environment Facility (GEF), the United Nations Development Programme, and the United Nations Environment Programme. These projects focus on isotope hydrological investigations of the:

✦ Nubian Aquifer System shared by Chad, Egypt, Libya and Sudan;

✦ Northwestern Sahara Aquifer System shared by Algeria, Libya and Tunisia;

✦ Iullemeden Aquifer System shared by Mail, Niger and Nigeria.

Advancing Knowledge about the Nubian Aquifer

The Nubian aquifer, shared by Chad, Egypt, Libya and Sudan, is of significant importance as a source of drinking water and for irrigation. The ancient waters of the Nubian stretch approximately two million square kilometers beneath these four countries of northeast Africa. The aquifer is a significant source of drinking water and irrigation and is the only source of freshwater in Egypt's western desert, which covers about 67% of the country's total land area.

Since 2003, the IAEA has been helping the Nubian countries use isotope techniques for mapping water resources. What is known so far is that under present climatic conditions, the Nubian's groundwater is sparsely recharged by Nile water seepage in a few areas, by precipitation in some mountain regions, and by groundwater influx from the Blue Nile/Main Nile Rift system.

The aim of the IAEA project is to expand and consolidate the scientific knowledge and database on the Nubian and develop a groundwater management plan based on a monitoring network for the aquifer. Setting up a management framework for the aquifer will be an important contribution to the region's development and eventually lead to sustainable production of drinking water and improved agricultural production.

The IAEA entered into a partnership with Global Environment Facility (GEF) in 2003 to develop a framework for sustainable management of the Nubian Aquifer, using isotope hydrology. The IAEA's work to help the Nubian countries study and manage shared groundwater supplies recently received a matching grant of $1 million from the GEF, based in Washington, D.C. The grant is being provided via the United Nations Development Program. The GEF funding will extend the scope of the IAEA-supported cooperative programme and will enable the countries that use the aquifer to develop an effective groundwater management plan.

Through these and other channels, the science and applications of isotope hydrology are advancing the world's knowledge of aquifer systems. With the right information in hand, the right decisions can be made to protect and preserve groundwater resources for generations to come.

Pradeep Aggarwal is Head of the IAEA's Isotope Hydrology Section, Department of Nuclear Sciences and Applications. E-mail: P.aggarwal@iaea.org

Ali Boussaha is the Head of the IAEA's Africa Section, Department of Technical Cooperation. E-mail: A.boussaha@iaea.org