

## Water



# Isotope Hydrology for Global Water Security and Sustainability



Oxygen isotope fingerprints of water give information about its origin and age, and they are measured by equilibrating water samples with CO<sub>2</sub> gas in the laboratory using mass spectrometry. (Photo: IAEA)

### SUMMARY

1. Access to fresh water is key for human well-being and development, so ensuring water security is essential.
2. Groundwater constitutes over 95% of available fresh water globally.
3. Isotope techniques help to determine groundwater age and replenishment rates, enabling countries to better manage their fresh water resources in a sustainable way.
4. The IAEA raises awareness of the benefits of isotope techniques and provides IAEA Member States wishing to assess their water resources and develop effective national water management strategies and policies with support in applying isotope techniques.

### INTRODUCTION

Ensuring access to enough fresh water to meet the demands of a growing world population and ensure healthy ecosystems is a global challenge. To manage fresh water in a sustainable way, decision makers need to understand the hydrological status and water availability needs of specific geographical regions.

Poor management of water resources often leads to declining water levels in aquifers, as well as to water pollution. The IAEA supports Member States in applying isotope hydrology techniques to tackle water-related challenges. This support also contributes to the achievement of Sustainable Development Goal 6, which calls for access to safe water for all by 2030.

## HOW MUCH FRESH WATER IS THERE?

Around 94% of all the water on Earth is seawater, which is unsuitable for human consumption. The remaining 6% — fresh water — mostly exists in the form of ice in the polar regions. Accessible fresh water is mainly located in groundwater aquifers (95%), with only a small percentage (5%) in rivers and lakes. Groundwater is therefore the major source of fresh water for human use worldwide, and its importance is increasing as the population grows.

## ISOTOPE HYDROLOGY PROVIDES INFORMATION ABOUT WATER

Environmental isotopes provide a unique insight into the source of water, as well as its history and movement through the water cycle. These data are important for decision makers to adopt appropriate environmental and conservation policies.

Water molecules carry unique ‘fingerprints’ based on their differing proportions of stable isotopes, which are chemical elements with atoms that have the same number of protons, but a different number of neutrons. Water molecules are made up of atoms of hydrogen and oxygen, but these atoms exist in different isotopes, and it is by measuring these isotopes that we can discover information about the history of water.

Radioisotopes are unstable and are constantly releasing energy called radioactivity as they exponentially decay to regain stability. By knowing the half-life of a radioisotope and its content in water, scientists can determine the age of water that contains those radioisotopes. This allows scientists to determine the age of water and the replenishment rates of aquifers, which can range from a few decades to millions of years.

Stable isotopes do not disintegrate and are present in the water molecule. Scientists use the stable isotope content in surface water and groundwater as ‘fingerprints’ to detect various factors and processes, including the sources and history of water, past and

present rainfall conditions, replenishment of aquifers, mixing and interactions of water bodies, evaporation processes, geothermal resources and pollution processes.

Isotope techniques constitute a key scientific method to trace fresh water movement and assess the age and replenishment rate of available groundwater. Isotope technologies are effectively applied to determine the source, age, movement and interactions of water both above and below ground. The data obtained can be visualized in hydrological vulnerability maps to enable experts to take decisions on sustainable water resource management.

## CAPACITY BUILDING: THE IAEA'S SUPPORT

National water resource assessments are needed to enhance Member States' abilities to meet water supply demands and better address water security. The IAEA helps countries understand the water cycle by applying isotope techniques.

Capacity building activities for achieving water security are focused on:

- The development and promotion of easier, low-cost methods for stable isotope and radioisotope analysis to strengthen capacity in Member States;
- Providing training courses and conducting coordinated research projects;
- Extensive hands-on training and analytical services provided at the state-of-the-art IAEA Isotope Hydrology Laboratory;
- Establishing Collaborating Centres for isotope analysis for Member States that are not equipped with the required analytical facilities to carry out such research;
- Incorporating IAEA Water Availability Enhancement (IWAVE) approaches to support Member States in more effectively including nuclear techniques in their assessments of national water resources;

- Collaborating with advanced research groups to help in the delivery of the key outputs of the IAEA Water Resources Programme; and
- Supporting the implementation of IAEA groundwater assessment projects and studies in large transboundary and regional aquifers.

## SNAPSHOT OF SUCCESS STORIES

The IAEA promotes the use of isotope hydrology by training national experts to identify and assess the capacity of groundwater resources; enabling the use of isotope tracers to gather essential data about the origins and behaviour of pollutants; and supporting scientific databases that inform water use policies in Member States. Some of the recent achievements of the IAEA and its Member States in this area are set out below.

- The IAEA, through a regional technical cooperation (TC) project entitled ‘Integrated and Sustainable Management of Shared Aquifer Systems and Basins of the Sahel Region’, has assisted 13 Sahel countries in using nuclear technology to determine the origins, flow paths and replenishment rates of the main groundwater systems and to assess the groundwater’s quality

By building capacities in water sampling and isotope hydrology methods, the IAEA has enabled these countries to study their main aquifers, as well as the interaction between water bodies, and to assess the vulnerability of groundwater to pollution and the impact of climate on water distribution and availability. These factors all affect the quality and availability of fresh water in the Sahel region.

- Morocco’s Sebou Basin contains approximately 30% of the country’s surface water resources. In order to better understand the interaction between surface water and groundwater in the basin, a national TC project supported a comprehensive study of the hydrological dynamics of the region. This study identified the



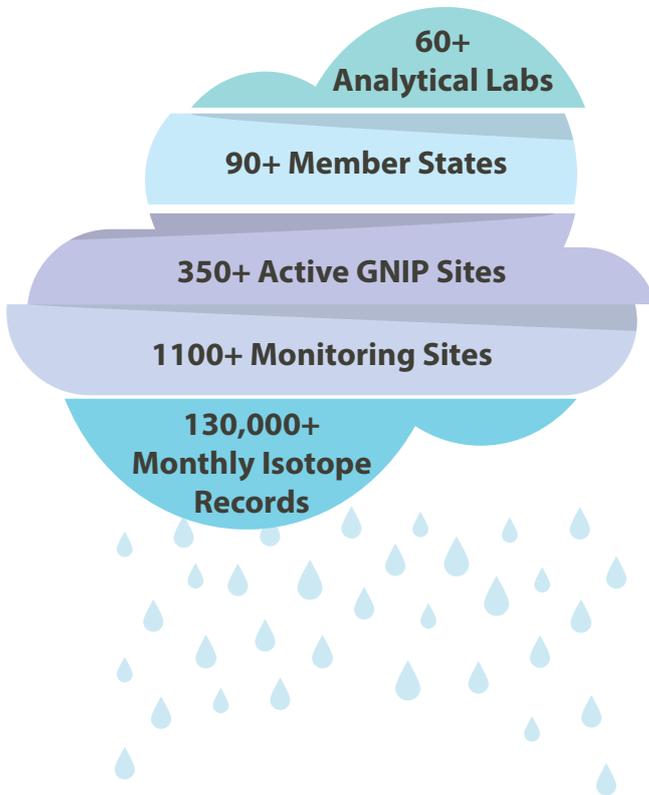
**Researchers from the University of Bangui take water samples from a well in the Central African Republic.**

(Photo: L.Gil/IAEA)

source of groundwater salinity in addition to revealing high concentrations of nitrate caused by local agricultural activities.

- A lack of hydrological data has prevented the effective management of Argentina’s El Plata Basin, which contains more than 85% of the country’s surface water resources. A national TC project has equipped Argentine counterparts with the skills and equipment needed to identify the age, flow and replenishment rate of groundwater sources.
- In the Asia and Pacific region, the city of Tacloban in the Philippines endured repeated typhoons, provoking storm surges that carry the risk of contaminating groundwater wells with saltwater and contaminants. Through the TC programme, and with the support of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, isotopic techniques were deployed to effectively characterize the aquifer on which Tacloban rests. The IAEA was able to authoritatively confirm that the drinking water is safe, potable and is sufficiently replenished.

## GNIP in Numbers



## THE GLOBAL NETWORK OF ISOTOPES IN PRECIPITATION

The Global Network of Isotopes in Precipitation (GNIP) is coordinated by the IAEA in cooperation with the World Meteorological Organization (WMO) and currently comprises about 380 global observation sites. The IAEA provides Member States with advice, as well as logistical and technical support, to assist new monitoring stations in the sampling of precipitation for isotopic analysis. The IAEA also maintains the long-term quality of the online GNIP database, which

comprises archived data collections from over 1100 observation sites in more than 100 countries and territories spanning over 55 years. GNIP is used by scientists to inform numerous practical applications, including water balance modelling, groundwater recharge and climate reconstructions.

The IAEA Isotope Hydrology Laboratory is a key player in analysing precipitation samples collected through GNIP, and it collaborates with over 350 international laboratories, many of which established or supported through relevant IAEA projects, in contributing to GNIP sample analysis.

The GNIP database currently houses over 130 000 individual isotope data records and is freely available to the public via a platform on the IAEA website, known as 'WISER' (<https://nucleus.iaea.org/water>).

## AREAS WHERE MEMBER STATES MAY BENEFIT FROM IAEA ASSISTANCE

- The IAEA encourages Member States to adopt isotope hydrology to help assess and manage their fresh water resources and to identify the environmental changes that might affect water availability and quality.
- The IAEA provides Member States with a high-quality global isotope database for conducting water resources investigations and climate modelling.
- The IAEA builds capacities in Member States for the application of isotope data and methodologies to assess and use groundwater in a sustainable manner.

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