Manage your water budget with the help of the tritium/helium-3 technique

By Nicole Jawerth

Managing water is like managing money in your bank account: you need to know exactly how much will be coming in, how much you can take out, and what could cause that to change. A miscalculation could have serious, potentially long-lasting consequences. In the world of water, this could mean water shortages or contaminated, unusable water resources.

To set up a reliable water budget, one of the key factors is knowing the exact age of water. For young water, which is more likely to be affected by current climate conditions and contamination, scientists use the tritium/helium-3 technique. With this and other techniques, scientists from 23 countries are working with the IAEA to collect data about water resources.

"The age of water tells you where it most likely came from, how quickly it is replenished, and how likely it is to be contaminated," said Hamid Marah, Scientific Director at Morocco's National Centre for Nuclear Energy, Sciences and Technology (CNESTEN). "With the tritium/helium-3 technique, we can say if water is 1, 5 or 25 years old instead of just saying it's young, old or both."

Scientists use isotopic techniques to study the age and origin of water from springs in northern Morocco.
(Photo: CNESTEN)

The age of water can range from a few months to millions of years. If water is one year old, for example, this means it will take one year for it to be replenished and is much more likely to be affected by current climate conditions and contaminants. If water is 50 000 years old, it will take 50 000 years to be replenished and is less likely to be contaminated or affected by changes in the current climate.

Nearly all of the world's available fresh water supplies are found in aquifers, which are the porous layers of permeable rock under the earth's surface. The water they contain is called groundwater. As groundwater is recharged, or replenished, it eventually flows into the sea or out onto the earth's surface naturally as rivers, springs and lakes.

"The growing demand for groundwater, combined with the impact of agriculture, climate change and human activity makes sustainability even more important," Marah said. "By extracting too much water from an aquifer, the level of water goes down and this can be catastrophic. We are not talking about 10 to 20 years from now: its impact lasts for generations."

The tritium/helium-3 technique is one of the most commonly used techniques for studying young water, which is water under 60 years old (see The Science box). The data collected from these studies can help decision makers develop more targeted and sustainable water resource management strategies and policies.

"Using nuclear techniques for water resource studies is breaking paradigms and changing our classical understanding of the key drivers controlling hydrological processes," said Ricardo Sánchez-Murillo, Isotope Hydrologist and Associate Professor at the National University of Costa Rica. "In Costa Rica, for example, results from using isotopic techniques are making their way into water management plans and decision making, helping the country achieve United Nations Sustainable Development Goal 6 on water by 2030."

A more exact budget

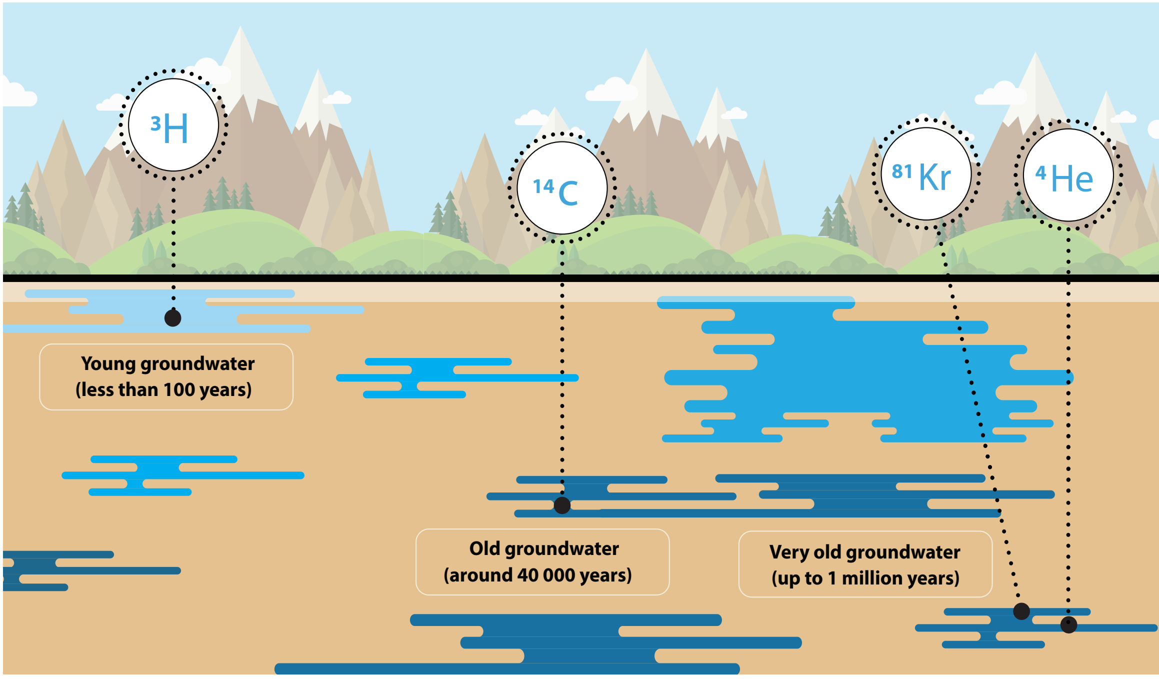
The tritium/helium-3 technique has become an increasingly important technique over the last decade because previous methods using just tritium are becoming less useful.

“Tritium can tell us the age of groundwater and whether it’s being recharged, which is very important information, but tritium alone cannot give us the level of detail we need. Decision makers need to know more: what does it mean that the water is young? How young is young?” Marah said. Due to atmospheric tests of thermonuclear devices in the 1950s, levels of tritium in the atmosphere sharply increased in the 1960s and have since gradually declined. “From the 1960s to 1990s, tritium was a good tracer, but today there is less tritium in the atmosphere because it has been decaying into helium-3, so we now focus more on the ratio of tritium to helium-3, which is much more precise.”

Helium is a noble gas, which means it is stable and does not have chemical reactions with other elements found in rocks or water. This makes it a consistent and reliable reference point. By knowing the concentration of helium that comes from tritium — helium-3 — compared to the total helium in the water, as well as the concentration of other noble gases, scientists can determine the exact age of young water.

“The use of noble gases for water studies is growing because now analytical devices have improved enough to detect the very small amounts these gases come in,” said Takuya Matsumoto, an isotope analyst at the IAEA. “For many countries, though, it is not economical or feasible to set up their own labs to do these analyses. The IAEA Isotope Hydrology Laboratory makes this service available to countries so they can benefit from this sophisticated technique.”

The IAEA Isotope Hydrology Laboratory is one of just a handful of laboratories in the world capable of performing these analyses. Beginning in 2010, a team of IAEA and external experts from ten countries spent six years setting up, calibrating and testing the IAEA’s mass spectrometer machine, as well as the mathematical model for analysing results. They also developed guidelines for using the tritium/helium-3 technique. The lab has since been working around the clock processing between 300 to 400 samples each year from countries worldwide.



Naturally occurring radioactive isotopes present in water, such as tritium (^{3}H) and carbon-14 (^{14}C), and noble gas isotopes dissolved in the water, such as krypton-81 (^{81}Kr), can be used to estimate groundwater age.

(Image: IAEA)

THE SCIENCE

Tritium is one of the three isotopes of hydrogen. As a radioactive isotope, tritium decays over a certain period of time and turns into helium-3, a stable isotope, which does not decay. Scientists know that it takes about 12 years for half of tritium atoms in water to decay into helium-3.

Scientists use a specialized machine called a mass spectrometer to sort the isotopes by weight and identify their concentrations. By knowing these concentrations and how long it takes for tritium to become helium-3, scientists can track and determine how old the water is and how often it is replenished.