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With a Push From the U.N., Water Reveals Its Secrets

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VIENNA - The forecast, courtesy of the United Nations, is grim.

Today, more than a billion people lack access to safe drinking water. Polluted water contributes, each year, to the death of about 15 million children under age 5. By midcentury, between two billion and seven billion people will face water shortages.

"No region will be spared from the impact of this crisis," Koichiro Matsuura, director general of Unesco, recently warned. "Water supplies are falling while the demand is dramatically growing."

He estimated that in the next two decades the average amount of water available per person on the planet will shrink by a third.

But the United Nations is also working hard on solutions, helping poor countries learn a subtle art that lets them better manage their water resources to avoid tragedy.

The method is known as isotope hydrology. Cheap and reliable, it takes advantage of the fact that water molecules carry unique fingerprints, based in part on differing proportions of the oxygen and hydrogen isotopes that constitute all water. Isotopes are forms of the same element that have variable numbers of neutrons in their nuclei.

Using the tools of isotope hydrology, scientists can discover the age, origins, size, flow and fate of a water source. And that information, in turn, can guide sound water-use policy, letting water engineers better map underground aquifers, conserve supplies and control pollution.

For instance, if the method reveals that the water in a well is young and recently derived from rain, villagers can pump away vigorously. But if it turns out to be very old - what scientists call fossil water - they need to move gingerly, taking care not to exhaust the water supply.

"You take it out once, like oil," Werner Burkart, head of the nuclear science programs of the International Atomic Energy Agency, said in an interview.

The United Nations group, best known for fighting the spread of nuclear arms, is leading the hydrology effort. Based in Vienna, it works at developing techniques as well as sharing them with scientists around the world.

"We do a lot of capability building and training of local people, so it becomes sustainable - so we don't have to inject support all the time," said Ana María Cetto, the agency's head of technical cooperation. "They're building their own capacity to manage their own resources."

A little money goes a long way. Each year, the isotope hydrology program spends only about \$2 million on research and \$5 million to aid developing states. Still, that is enough to finance 84 projects in more than 50 countries, including Bangladesh, Costa Rica, Ethiopia, Morocco and Senegal.

"If you look at the Middle East, everywhere you are using old water," said Pradeep Aggarwal, the head of the agency's isotope hydrology unit. "It was laid down 10,000, maybe 100,000 years ago. So you have to understand there's a limit to how long this will go."

After more than 25 years of cooperative work, the agency has gathered so much information that it is now fashioning a detailed portrait of the planet's water resources that could help prevent future crises and reduce regional friction that may erupt in water wars.

"We're talking about food security, sustainable development," Dr. Aggarwal said. "If it's based on unsustainable water resources, you jeopardize everything."

Oceans and seas constitute 97 percent of the planet's waters. The remaining 3 percent is fresh water, most locked up as ice, soil moisture and deep groundwater. What is available to people - mainly as rivers, lakes, aquifers, reservoirs and wetlands - comes down to less than 1 percent.

Using that fresh water wisely requires considerable knowledge of the earth's water cycle, the outlines of which are well known, centering on evaporation and rain, runoff and seepage. But local riddles abound. The puzzles can include how often a particular body of water is renewed, where it flows and whether different bodies are physically linked through underground flows.

In the past, water engineers would address such unknowns by carefully measuring rain and the levels of rivers and other bodies of water for many decades - typically a half-century or more. It usually took that long to learn the subtleties of the local cycles.

However, isotope hydrology can do it in days, quickly illuminating water's passage through the depths. "You really need to know how the water gets in and moves," said Dr. Aggarwal. "Isotopes let you do that in a cost-effective way."

The raw material is everywhere. Air, soil and water naturally contain oxygen in two forms - oxygen 16 and oxygen 18, which has two extra neutrons in its nucleus. Oxygen 18 represents about 1 oxygen atom in every 500. Because it is heavier than oxygen 16, more is left behind when water evaporates. As a result, seawater is rich in oxygen 18; rain and snow are relatively poor, and increasingly so the further inland they fall.

These gradients are echoed underground. The tools of isotope hydrology let scientists see the differences, creating a window into the depths. For instance, comparing samples from different wells can reveal whether the groundwater mixes or becomes isolated in separate pools.

In Ethiopia, the International Atomic Energy Agency used such techniques to help a foundering project. To supply water to the capital, Addis Ababa, the Ethiopians drilled 25 large wells, assuming that a not-too-distant river would renew the aquifer. But when the pumping started, water levels fell much faster than predicted.

"They didn't understand the hydrology," Dr. Aggarwal recalled. "They came to us for help."

In a two-day survey, the agency discovered little connection between the river and the wells, prompting an overhaul of the project that put new emphasis on judicious use. Scientists have now mapped the speed and direction of the area's limited groundwater flow.

Ethiopia's reaction to the episode was to demand that its water scientists put greater emphasis on isotope hydrology, making it "a standard tool for the country," said Mohamed ElBaradei, the agency's director general.

Over continents and wide lands, the study of isotope signatures can reveal if aquifers flow under national borders, helping neighbors collaborate on the intelligent use of scarce water.

That is just what the atomic energy agency is doing in the blistering heat of the Eastern Sahara desert, with Libya, Chad, Egypt and Sudan. They have joined together to map the shared water resources of the Nubian aquifer, a vast subterranean body whose lobes range over nearly a million square miles, an area bigger than Iran and Iraq combined.

"We're trying to elucidate the connections," said Mokdad Maksoudi, an expert on African technical cooperation at the agency. "Some parts of the aquifer are very old, with fossil water. Some are recharged through the Nile.

"We're trying to understand the recharge, so the countries can precisely gauge the best policies," he said.

The stakes are high because areas of fossil water are vulnerable to quick depletion.

A main goal of isotope hydrology is to discover the age of groundwater, defined as the last time it had contact with the atmosphere.

This is calculated in many ways. Cool temperatures, for example, lower the concentrations of oxygen 18, and thus, unusually low amounts of the atom in groundwater imply that the body of water arose long ago, during ice ages and cooler climatic eras.

A more exact way to determine age is to measure carbon 14, a radioactive isotope that water bears in minute quantities and that, with clocklike precision, steadily decays into other substances, allowing researchers to calculate the elapsed time.

Scientists have used such methods to address a humanitarian crisis in Bangladesh that the World Health Organization calls the "largest mass poisoning of a population in history."

Millions of people in Bangladesh, one of the world's poorest countries, drink arsenic-contaminated water, the poison gradually debilitating its victims before spawning cancers that kill them.

Good intentions lay behind this horror. For decades, the government and aid groups had urged people to give up pond water, often a carrier of lethal disease, and instead to dig shallow wells. But no one tested the aquifers for arsenic.

For years, the atomic energy agency and its isotope hydrologists, using the carbon 14 and oxygen 18 methods, have worked closely with the Bangladeshis to help them map aquifer mazes and identify safer water supplies.

The news is mixed. The scientists have found that the arsenic tends to reside in shallow aquifers, and that deeper levels bear none of the deadly poison. In some cases, however, these deep aquifers have connections to the shallower ones, and pumping them out could draw in the contaminated water.

"So you can have water at 100 meters that is arsenic-free today, but could become polluted in the future," Dr. Aggarwal said.

He added that the teams have discovered even deeper waters that are unconnected to the surface and will probably stay pure. But the isotope-dating methods show that these very deep aquifers are old and not undergoing renewal, calling for careful conservation. "If you pump it out in a major way," he said, "it will hurt."

The flow of detailed hydrological information, he said, has been "a tremendous boost" to the government's understanding and has helped it make substantial changes in policy. "Part of solving the problem," Dr. Aggarwal said, "is to understand its origin and extent."

Experts agree that hydrology will become even more important in the future, as growing water shortages intensify conflicts between states, whether or not they result in water wars. Some analysts see clean water as poised to supplant oil as the world's most contested natural resource.

Dr. Burkart of the atomic energy agency said that reliable information about the hidden world of water could only help dissipate international tensions.

"The more you know," he said, "the better."