Managing urban water: the role of isotope hydrology and what the Cape Town water crisis taught us

By Jodie Miller

The 2017 to 2018 water crisis in Cape Town, South Africa, provided an opportunity to evaluate the role of isotope hydrology in maintaining the integrity of urban water supply networks. The integrity of water supplies is critical to the long-term sustainability of southern Africa's economy, and requires an understanding of the relationship between climate, water resource utilization and the implications of this relationship on socio-economic factors. A region's water budget — the relationship between water input and output — has significant socio-economic implications, including the ability to support urban centres, reduce poverty, protect food and energy supplies and develop scientific skills to inform local water management strategies.

In recent years, these issues have come to a head as severe drought has affected Cape Town, a city at the southern tip of Africa with a population of approximately 3.8 million. Below average rainfall between 2014 and 2017 resulted in Cape Town experiencing extreme water stress over the summer of 2017 to 2018. The city derives most of its water supplies from six surface water storage facilities with a combined total capacity of 828 991 million litres. By March 2018, the total storage in these facilities reached its lowest recorded level at less than 20%, with the largest of the reservoirs, the Theewaterskloof reservoir, at only 13.5% of its 480 188 million litre capacity. Various pronouncements of an imminent 'Day Zero' were made — the day the city would turn off the municipal water supply to maintain the most critical infrastructure, such as hospitals. In response, all residents were required to reduce water consumption to just 50 litres per person per day.

In the end, 'Day Zero' never arrived. The city's collective efforts to save water allowed the stored water to last until the arrival of the winter rains. However, the possibility of shutting down the municipal water network transformed the way people use and value water and led to a real change in water use patterns. At the same time, the question of how a large urban centre could protect and supplement its short-term water security raised important scientific questions, including how we track and measure the relative contributions of many diverse water inputs to supply networks. Desalination, grey water recycling, direct rainwater harvesting and groundwater abstraction are all used to supplement surface water storage reservoirs across many municipal networks at a variety of scales. But these can compromise water quality. Managing both water quantity and quality in the light of increasingly diversified input streams requires new approaches and scientific tools to develop best practice strategies.

Urban isotope hydrology

Among the scientific tools available to help track the sources of the municipal network's different inputs is the study of the stable isotopes of water. The study and application of naturally occurring hydrogen and oxygen isotopes in the water cycle is at the core of isotope hydrology.

Because of widespread urbanization and population growth, urban isotope hydrology has gained traction in recent years as a tool to understand processes involved in urban water supply. The most important component of urban isotope hydrology is 'fingerprinting' the isotope characteristics of each input to the urban water network to track each component through the system. This information can be used by water managers to plan long and short-term water management policies, including monitoring relative contributions, residence times in the network, leakage and resultant losses from the system and pollution or contamination management.

Tap water samples collected from private homes throughout the town of Stellenbosch, home of Stellenbosch University and the epicentre of the country's premier wine-growing districts, were analysed to determine the oxygen-18 (^{18}O) and deuterium (^{2}H) isotope ratios. The results paint a fascinating

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Average rainfall since 2014 has made the water level at the Theewaterskloof dam in South Africa's Western Cape drop to critical levels.
(Photo: A. Silva Garduno/IAEA)

picture of how sensitive urban isotope hydrology is in 'seeing' fluctuations in the urban water network. Instead of the uniform water we physically see coming out of the taps, the isotope ratios record highs and lows, matching and diverging patterns.

In essence, isotopes provide the fingerprint of each segment of the local water supply network: the source, different treatment plant, and information on how long water remains in the distribution network. As water managers seek to secure long-term sustainable water supplies for growing urban centres the world over, urban isotope hydrology will become an essential component of the water manager's toolkit.

Jodie Miller collects a water sample in Western Cape.
(Photo: A. Silva Garduno/IAEA)