Investigating leaks in Dams & Reservoirs

Millions of people throughout the world depend on dams and reservoirs for electricity, water and flood protection. Dams require significant investment to build and maintain, and yet their usefulness and integrity are constantly threatened by leakage and sedimentation. Isotope hydrology techniques, combined with conventional analytical methods, are a cost-effective tool to reduce such threats. The International Atomic Energy Agency is promoting their use to protect these investments and improve management, particularly by supporting specialized teams of scientists and engineers to investigate dam leakage in African countries on request.

MICHAEL PICKSTOCK/WRENmedia

Dams represent large investments for developing countries.

Dams, ancient and modern

The oldest dams, for which there is documentary evidence, were located in Jordan some 5,000 years ago. Most ancient dams have long since disappeared but, exceptionally, some are still operational 1,000 years after being built. Modern, large dam construction continues today and represents a considerable initial investment and recurring maintenance costs thereafter. Studies have shown that large dams have an average lifespan of 22 years which means that many of those constructed in the '70s are today nearing the end of their useful life.

Millions of people depend on dams and reservoirs for domestic, industrial and agricultural water supply, for flood protection and for electricity. National economies are often highly dependent on the power generated by such dams. Furthermore, even when a dam comes to the end of its economically useful life, ensuring that it remains safe is a continuing economic burden. Prolonging the useful life of a dam is a priority for operators and national governments.

Even newly constructed dams are expected to lose, on average, 1% of reservoir capacity every year as a result of sedimentation, and millions of US dollars are invested in grouting and sealing due to real and suspected leaks.

Seepage vs. leakage

All dams are designed to lose some water through seepage. This helps make a dam more stable. Controls to keep seepage at an acceptably low level are designed and incorporated into the dam and its foundations.

Leakage occurs when seepage concentrates through a weak area in the dam or works its way in the foundation or abutment. Leakage can present a serious problem, especially if it also carries sediment - an indication that erosion could threaten dam stability.

Field investigations

When a dam appears to be leaking, there are enormous pressures on operators to repair the leak without delay. This is not only to ensure continued efficient power generation, for example, but also for safety reasons. Very large sums of money are spent on construction engineering to repair or mitigate:

- Leaks from reservoirs that flow under and around dams;
- Leakage through dams, foundations and abutments; and
- Sedimentation within the reservoir.

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Isotope Hydrology

One of the most efficient and least costly methods of detecting the origin of leaks is to use isotope investigations, specifically natural and artificial tracers, to follow the movement of water. This will reveal where leakage is occuring and avoid the costly, yet common, trial and error method of repair. Such tests may also reveal that sudden changes in water flow downstream are not necessarily due to a leak from the reservoir, but may actually be from natural groundwater sources unconnected with the dam.
(See box: The Costa Rican Experience)

Isotope analysis is a particularly useful tool in the early stages of siting, planning and constructing a dam. Most countries spend large sums of money on physical core sampling but the knowledge of water movement that consulting engineers require to plan how to prevent future leaks, can be obtained more efficiently by using isotope techniques in support of conventional geology and hydrology. Effective dam management programmes must be based on the best possible understanding of all relevant information.

Using an artificial tracer to identify the source of leakage.

EDMUNDO GARCIA AGUDO/IAEA

The Costa Rican Experience

A landslide, close to the Arenal hydropower dam in a volcanic, seismic region of Costa Rica, together with the appearance of a full river of water two kilometres downstream from the dam, was causing national authorities grave concern. It was feared that an earthquake had damaged the dam structure, allowing water from the reservoir to leak through, with serious consequences for the safety of the region. A team of IAEA-trained engineers were able to demonstrate that the landslide was caused by the accumulation of infiltrated rain in the area and not from the reservoir itself. Instead of having to reinforce the entire dam structure, a very expensive operation, the authorities were able to install drain systems, which solved the problem at relatively low cost.

In another instance, construction engineers were both puzzled and worried when a tunnel, built through rock and designed to feed water into the turbines of the Angostura hydropower station in Costa Rica, unexpectedly filled with water during construction. Isotope tracers revealed that the water came from a creek that had infiltrated a geological fault more than a kilometre away. Instead of posing a threat to the safety of the dam, the water could be used to supplement the reservoir water, thereby increasing electricity generation efficiency.

How do isotope tracers work?

One body of water looks much like another but, at the atomic level, they can be distinguished by their natural isotopic composition or 'fingerprint'. In the water molecule, it is the relative abundance of the stable isotopes, Hydrogen-2 (deuterium) and Oxygen-18, that are used for identification. Artificial isotopes may also be added to the water to label it. The use of artificial tracers, such as Iodine-131 and Gold-198, are particularly helpful in understanding leakage problems. Without tracing techniques, it is very difficult to be sure exactly how water is really flowing.

Making the technology better known

Isotope hydrology is a powerful tool. While its use can save significant sums of money when deciding where to site a dam, how to plan its construction and how to minimize repair and maintenance costs, fewer than 5% of dam operators understand this role. Furthermore, isotope hydrologists are sometimes unaware of the needs of the engineers brought in to solve dam management problems.

A regional IAEA Model Project seeks to overcome this lack of awareness in Africa. Through training and support, specialized teams using experts from the region are being established to investigate reported leaking dams and reservoirs in the participating countries and propose remedial measures. Where required, the specialized team will monitor the implementation of the recommended remedial measures. Through this process, it is expected that the specialized teams will eventually be able to provide a self-financing, consultancy service, bringing expertise to the regions where it is most needed.

In coming years, dam operators and the development organizations that finance these investments will have increasing access to this effective tool for ensuring safety and sustainability.

International Atomic Energy Agency
Department of Technical Co-operation
Wagramer Strasse 5
A-1400 Vienna, Austria
Tel: (+43 1) 2600-26005
Fax: (+43 1) 2600-29500
E-mail: tcprogramme@iaea.org

Designed and produced by WREN*media*, Fressingfield, Eye, Suffolk IP21 5SA, UK