

Isotope mapping of groundwater pollution and renewal

By Joel Podgorski, Michael Berg and Rolf Kipfer

Obtaining good quality groundwater for drinking, industry and agriculture is becoming increasingly difficult due to population growth, water overexploitation, land use and climatic changes. Groundwater resources provide 50% of the world's drinking water and 43% of the water used for irrigation. But near-surface groundwater aquifers are easily contaminated by fertilizer and pesticides, chemical spills and wastewater. Furthermore, overexploitation and uncontrolled withdrawal of water from aquifers can lead to a loss of water supply due to rapidly declining water levels.

To assist water managers in protecting and conserving groundwater resources, aquifer vulnerability maps are useful. They help identify areas of the landscape that are particularly sensitive to contamination or overexploitation and therefore help inform water management and remediation efforts. Mapping groundwater vulnerability is also key to supporting United Nations Sustainable Development Goal 6, or SDG 6, which calls for securing sustainable water for all, in particular safe water (Target 6.1). It also advocates for integrated water resources management (Target 6.5).

Aquifer vulnerability

From a technical perspective, there are many ways of assessing an aquifer's vulnerability to water pollution or overexploitation. In the past, general geological features, borehole data and regional hydrological data were used. However, these are often imprecise or inaccurate, or missing altogether. Complex computer models have also been used, but these require accurate data and often suffer from high computational costs and limited data availability, and as a result are usually restricted to small study areas.

Chemical indicators and statistical analyses can be used to link available environmental data to groundwater vulnerability. One example is nitrate, which is a water pollutant introduced mainly by agriculture that is easy and inexpensive to measure. To generate groundwater vulnerability or protection maps, the pollutant (such as nitrate) or vulnerability

indicator data must be available over an appropriate area of concern to produce reliable and accurate predictive maps.

Online mapping

To show that statistical mapping of aquifer vulnerability is effective, data from an existing vulnerability map in Canada were re-analysed using the free online Groundwater Assessment Platform (GAP) (www.gapmaps.org). The aquifer vulnerability maps by GAP produced an accurate probability prediction map of high aquifer vulnerability, without the need to collect a lot of data from the entire study area.

Using tritium to map water recharge rates

Trace amounts of the radioisotope tritium occur naturally in rainfall by an interaction of cosmic radiation in the upper atmosphere. During the above-ground nuclear weapons testing that took place between 1952 and 1962, vast amounts of tritium were injected into the water cycle, which, as a result, became a measurable indicator of modern groundwater recharge. Although global tritium levels in rainfall have since declined to low pre-bomb natural levels, sensitive analytical detection capabilities still allow us to accurately detect the isotope.

One principle advantage of using tritium, or ^3H , for mapping is that the isotope is a fundamental building block of the water molecule ($^1\text{H}^3\text{HO}$) and is therefore present in rainfall. This means that any detectable tritium in other parts of the water cycle — rivers, lakes, groundwater — reveals the presence of contemporary water from recent rainfall. This can tell us that the water we are dealing with is from the past few decades — data that we can use to directly identify and map aquifers' susceptibility to contamination via rainfall, even if the groundwater has never been contaminated.

So far, statistical mapping methods for estimating aquifer vulnerability have generally not been widely used with tritium



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Eawag is a Swiss water research institute concerned with concepts and technologies for dealing sustainably with water bodies and water as a resource.

In collaboration with universities, other research institutions, public bodies, industry and non-governmental organizations,

Eawag works with its global network to harmonize ecological, economic and social interests in respect of water usage.



measurements. This is because tritium is not commonly included in groundwater studies, and the analysis is still costly. In the meantime, other easily collected water quality or isotopic parameters can be used in vulnerability mapping. For example, carbon-14, the stable isotopic composition of water (^2H , ^{18}O), nitrate and chloride can also help to evaluate the age of groundwater or check if it has been exposed to contamination.

The statistical and online mapping of aquifer vulnerability and groundwater replenishment using isotopes and chemistry represents a significant advancement and a practical application of tritium and related natural isotopic tracers. Currently, there is great potential in applying the IAEA's extensive global datasets on ^3H , ^2H and ^{18}O , along with the geostatistical mapping described above, to global ground and surface water quality and

quantity issues. New efforts are being made in this area by the IAEA in cooperation with the Swiss Federal Institute of Aquatic Science and Technology (Eawag) toward evidence-based assessments and mapping of safe drinking water on a global scale. We also expect the use of isotope mapping to assist experts from around the world in managing groundwater in a balanced and sustainable manner.

An index aquifer vulnerability study from western Canada (left) compared with a new logistic regression map of these vulnerability index values on the online GAP platform (right). The red colour shows areas with the highest vulnerability. The green areas are less vulnerable or adequately protected from surface contamination.

(Image: Eawag)

This piece was written in collaboration with IAEA isotope hydrologists.

