Isotope Hydrology in the Sahel Zone

Northern Africa has recently experienced an exceptional period of severe drought. Practically no precipitation has been received during two or three years by large regions in the so-called Sahel zone, which extends over all Africa from West to East at a latitude between 10 and 20°N in the following countries: Senegal, Mauritania, Mali, Upper Volta, Niger, Nigeria, Chad, Sudan and Ethiopia.

Going from the Sahara in the North towards the South, the Sahel ('shore' in Arabic) is the zone where the desert ends, the vegetation starts to appear, and life becomes possible again. This zone is mainly inhabited by nomadic shepherds. Lack of precipitation means, therefore, lack of food for the cattle and, in turn, for the people. As a result of the long drought, most of the cattle have died; the nomads have been obliged to leave their usual living areas and have concentrated around towns and villages, where the local governmental authorities have organized assistance, with the help and support of other countries and international organizations.

Although precipitation is scarce even in normal years, important groundwater resources are present in the Sahel zone. However, groundwater is exploited mainly by dug wells, reaching only the upper part of the phreatic aquifer, which is also the one immediately affected by droughts (lowering of the water table). Deep groundwater is exploited only by a limited number of drilled wells.

In recent years several hydrogeological projects have been financed by the United Nations through UNDP in the Sahel countries, with the purpose of locating and evaluating groundwater resources and of developing their exploitation. The International Atomic Energy Agency has taken or takes part in many of these projects by providing isotopic analyses of groundwater.

Some of the most difficult questions to be answered in groundwater research in arid zones are:

Is the recharge of a given aquifer also taking place at present?
If so, from where does the major contribution to groundwater recharge come?
What is the age of groundwater?

Dug well sampled for isotopic analyses. Here practically no vegetation occurs; it is already the desert

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Dug well sampled for isotopic analyses

After sampling a dug well

Bush vegetation typical of the Sahel. These plants may survive long droughts

Often it is not possible to answer these questions with the classical hydrogeological and geophysical methods above, but the techniques based on the so-called environmental isotopes (^{18}O and ^{2}H, stable; ^{3}H and ^{14}C, radioactive) may provide an answer.

The concentrations of stable isotopes of oxygen and hydrogen, which are part of the water molecules, are a conservative property of groundwater. These isotopes are, therefore, among the most powerful and reliable geochemical tracers for establishing the origin of groundwater. On the other hand, tritium (^{3}H) and carbon-14 concentrations depend on the age of groundwater. Tritium, which has been introduced in large amounts and on a world-wide scale in the hydrological cycle for the past 20 years by atmospheric thermonuclear explosions, is an indicator of recent recharge, and its presence in groundwater shows that the aquifer is active. Carbon-14, produced at an almost constant rate by cosmic ray interaction with atmosphere, is introduced into groundwater by dissolution of soil CO_2 taking place in the unsaturated zone and in the saturated zone in proximity of the water table. Then the dissolved ^{14}C starts to decay and its concentration depends on the age of groundwater, which can be established, ideally, up to a limit of 30,000 years. Therefore, tritium is mainly used in shallow aquifers, while ^{14}C is mainly used in deep, confined aquifers.

The information provided by isotope techniques is in many cases extremely valuable for a better understanding of groundwater resources and a better planning of their exploitation, despite the problems which always occur in actual cases. In fact, natural processes, like mixing or interaction with the aquifer material, or practical difficulties such as insufficiency or even absence of auxiliary data concerning drillings, or impossibility of collecting samples from certain water horizons, etc., tend to complicate the issue in almost all cases. However, the data and experience accumulated over a period of about 15 years by the Section of Isotope Hydrology of the IAEA and by other laboratories in the world is often decisive in the interpretation of new data, in spite of the many difficulties.

In recent years, hydrological studies conducted by UNDP in Chad, Senegal, Mali (all in the Sahel zone) and in many other arid countries included isotopic investigations, which have been carried out by the IAEA. At present, similar investigation in foreseen for a UNDP project in Mauritania.

All these photographs were taken by IAEA staff member R. Gonfiantini, in Southern Mauritania.