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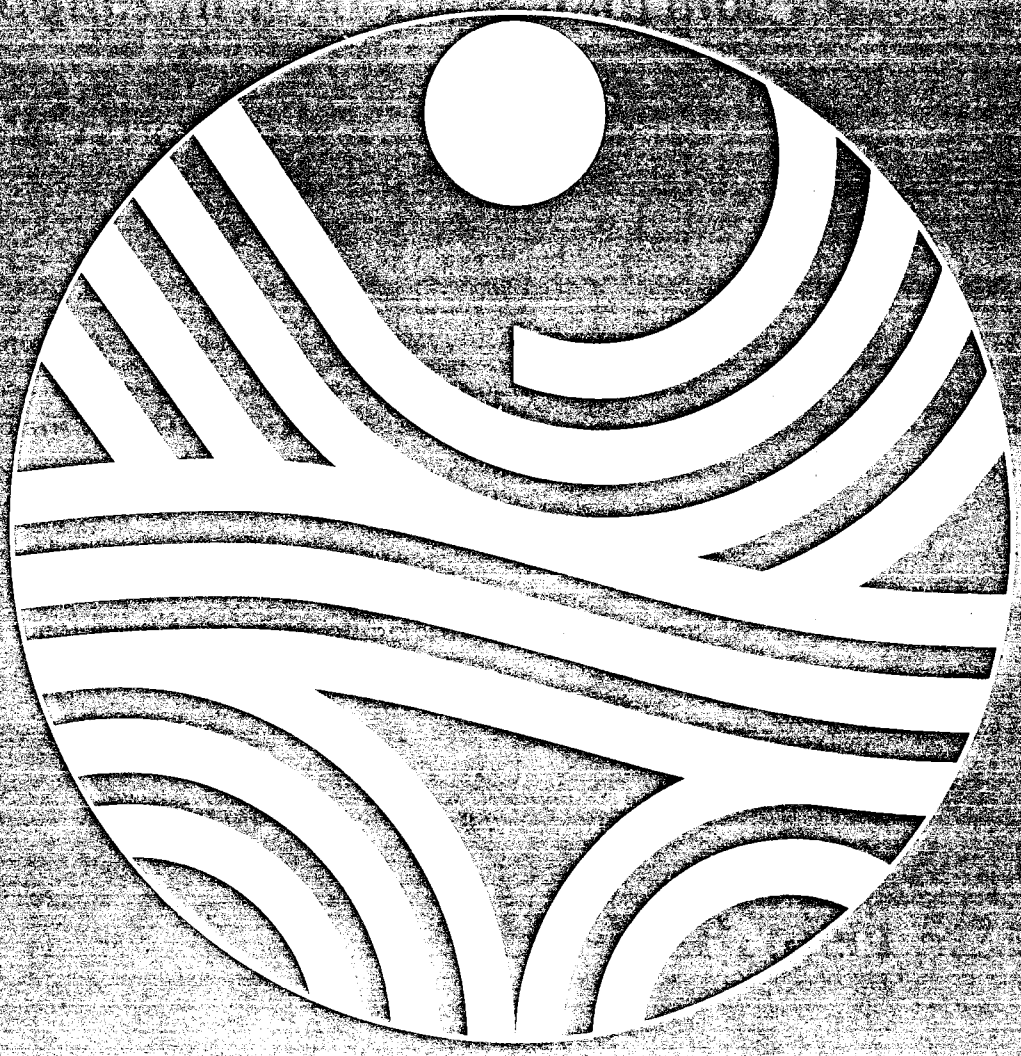
The use of environmental isotope techniques in arid zone hydrology

A critical review

by J. Ch. Fontes and W. M. Edmunds



Technical Documents in Hydrology

International
Hydrological Programme

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Preface

Although the total amount of water on Earth is generally assumed to have remained virtually constant during recorded history, periods of flood and drought have challenged the intellect of man to have the capacity to control the water resources available to him. Currently, the rapid growth of population, together with the extension of irrigated agriculture and industrial development, are stressing the quantity and quality aspects of the natural system. Because of the increasing problems, man has begun to realize that he can no longer follow a "use and discard" philosophy -- either with water resources or any other natural resource. As a result, the need for a consistent policy of rational management of water resources has become evident.

Rational water management, however, should be founded upon a thorough understanding of water availability and movement. Thus, as a contribution to the solution of the world's water problems, Unesco, in 1965, began the first worldwise programme of studies of the hydrological cycle -- the International Hydrological Decade (IHD). The research programme was complemented by a major effort in the field of hydrological education and training. The activities undertaken during the Decade proved to be of great interest and value to Member States. By the end of that period a majority of Unesco's Member States had formed IHD National Committees to carry out the relevant national activities and to participate in regional and international co-operation within the IHD programme. The knowledge of the world's water resources as an independent professional option and facilities for the training of hydrologists had been developed.

Conscious of the need to expand upon the efforts initiated during the International Hydrological Decade, and, following the recommendations of Member States, Unesco, in 1975, launched a new long-term intergovernmental programme, the **International Hydrological Programme (IHP)**, to follow the Decade.

Although the IHP is basically a scientific and educational programme, Unesco has been aware from the beginning of a need to direct its activities toward the practical solutions of the world's very real water resources problems. Accordingly, and in line with the recommendations of the 1977 United Nations Water Conference, the objectives of the International Hydrological Programme have been gradually expanded in order to cover not only hydrological processes considered in interrelationship with the environment and human activities, but also the scientific aspects of multi-purpose utilization and conservation of water resources to meet the needs of economic and social development. Thus, while maintaining IHP's scientific concept, the objectives have shifted perceptibly towards a multi-disciplinary approach to the assessment, planning, and rational management of water resources.

As part of Unesco's contribution to the objectives of the IHP, two publication series are issued: *Studies and Reports in Hydrology* and *Technical Papers in Hydrology*. In addition to these publications, and in order to expedite exchange of information, some works are issued in the form of *Technical Documents*.

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1. Introduction

A precise definition of arid zones is not straightforward, and there may be separate interpretations for scientists from different disciplines. To the hydrologist, arid zones are characterised by low average rainfall and the absence of perennial rivers. Generally these basic criteria are correlated with high mean annual temperatures and low atmospheric humidities giving rise to a high rate of potential evapotranspiration. Water resources are therefore limited to groundwaters which may be derived from annual, ephemeral or fossil replenishment, by a variety of possible recharge mechanisms.

Detailed studies of palaeoclimatic records show that arid zones may fluctuate geographically within various time scales, typically 10^3, 10^2, 10^1 a (see for example Street-Perrott et al., 1983). Therefore, replenishable groundwater resources may be available in regions where present day recharge is potentially very low. Similarly it may not be possible to correlate directly the presence of higher rainfall belts in certain areas in recent years (e.g. North Africa compared to the southern Sahara during the early 1970s) with the size of the local groundwater storage.

Palaeoclimatic studies of arid regions in recent years have advanced considerably our knowledge of the time scales of humid episodes during the late Pleistocene and Holocene (see e.g. Nicholson, 1982). Thus, for example we know that several very marked pluvial conditions (episodes) have occurred during the period ca. 12,000 - 3000 B.P. in northern Africa (Gasse et al., 1987), yet these episodes may not have been simultaneous from place to place (see for example Maley, 1973, Williams and Faure, 1980). Even during the relatively arid period from 3000 B.P. to the present, there is evidence of cyclic humid and arid episodes based on the historical record (Nicholson, 1980). Isotopic investigations of archaeological material, sediments and plant debris have played a significant role in providing this 'indirect' evidence of possible recharge of the major aquifers. However, the indirect

evidence must often be considered with caution since humidity may not directly correlate with aquifer recharge. It is important to obtain 'direct' evidence of groundwater replenishment by sampling the record which exists in the water itself. This applies equally to processes operating at the present day as to the palaeorecharge record.

The objective of this paper is to assess critically the use of isotope techniques for arid zone hydrology through a state of the art review. Emphasis is placed on the relative value of data from other disciplines, especially hydrogeology and geochemistry and on the requirements of 'conventional' data for proper interpretation of isotopic measurements. Attention will be paid also to the emergence of new concepts and methods in the use of environmental isotope techniques within the field of 'arid zone' hydrology.