THE STATE OF UNDERSTANDING ON GROUNDWATER RECHARGE FOR THE SUSTAINABLE MANAGEMENT OF TRANSBOUNDARY AQUIFER IN THE LAKE CHAD BASIN

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Abstract: Water resource management in the arid to semi-arid areas requires not only exploration and assessment of the available reserves, but also determination of groundwater recharge in order to evaluate the sustainable yield of the ressource. This paper highlights some key groundwater recharge studies on the Chad basin Quaternary aquifer using diverse methodologies : piezometric map, water balance, water table fluctuation method, water chemistry, environmental isotopic measurements in samples from groundwater and surface water and chloride mass balance technique. The results show that important recharge zones are located in topographically higher areas (Mandara Mountains, Guera and Batha massifs), and where there is exposed sand dunes. Indirect recharge to groundwater body is by seepage through the beds of Lake Chad, Rivers Logone-Chari, local ponds and non permanent rivers (Komadugu Yobe, Yedseram, Mayos).
Keywords: Lake Chad basin, groundwater recharge, water resource management, arid-semiarid, climate variability, human activities.

Introduction

In the Lake Chad basin (fig. 1) the use of groundwater as supply has increased dramatically. In order to assure the water supply to the growing population under human activities, changes in climate variabilty, growing demands and catchment degradation, groundwater recharge investigation is one of the main concerns for water managers in the coming decades. It is believed that such information can be of great use to all those concerned with the issues of water resources management in the arid and semi-arid areas. This study is part of a larger effort to improve the knowledge and understanding of groundwater resources and their proper management in the Lake Chad basin.

The Lake Chad basin is a sedimentary basin formed in the Mesozoic era. According to the geological classification two aquifers may be distinguished, the Quaternary and the Continental Terminal aquifers (fig. 2). The Quaternary aquifer consists of sandy, deltaic and lacustrine deposits. This aquifer is unconfined and locally known as the shallow aquifer. Its in direct hydraulic contact with the Logone-Chari river. The Continental Terminal (CT) aquifer including the Pliocen and Oligo-Miocen (Kilian, 1931; Ngounou Ngatcha *et al*., 2006) and, consists of sandstone and argillaceous sands. Key caracteristic of the CT are that it has generally been considered to be a classic example of an artesian aquifer system.

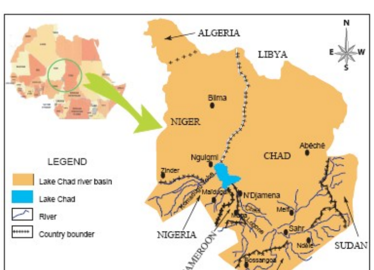

Fig. 1 Lake Chad watershed

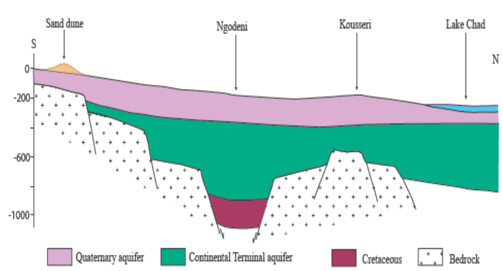

Fig. 2 Geological and hydrogeological formations in the lake Chad basin

Methods for groundwater recharge investigation in the Lake Chad basin

Over the last 40 years, much attention has been given to improving groundwater recharge investigation in the Lake Chad basin (UNESCO, 1969; Fontes *et al*., 1970; Ketchemen, 1992; Njitchoua & Ngounou Ngatcha, 1997; Edmunds *et al*., 1998; Goes, 1999; Djoret & Travi, 2001; Leduc *et al*., 2000; Ngounou Ngatcha *et al*., 2001; Gaultier, 2004; Goni, 2006; Ngounou Ngatcha *et al*., 2007a; Ngounou Ngatcha *et al*., 2007b). The main methods of investigation are shown in table 1. The more classical methods of groundwater investigation like hydrogeology and hydrogeochemistry are complemented with the methods of isotope hydrology and mathematical modelling.

Table 1: Methods for groundwater recharge investigation in the Lake Chad basin (blue is method tested and red the method not yet tested)

Methods	Water zone				Area of application in the Lake Chad basin
	Rainfall	Surface water	Unsaturated zone	Saturated zone	
Thornthwaite method			blue		Cameroon
Hydrogram of separation		blue			Komadugu Yobe
Water balance		blue		red	Hydrological basin
Water table fluctuation				blue	Cameroon, Chad, Niger, Nigeria
Lysimeter and Soil Physics			blue		Cameroon
Mathematical modelling		red		blue	Quaternary aquifer
Stable isotopes (^{18}O, ^{2}H)	blue	blue	red	blue	Cameroon, Chad, Niger, Nigeria
Tritium	blue	blue	red	blue	Cameroon, Chad, Niger, Nigeria
Carbon-14				blue	Cameroon, Chad, Niger
Chlore mass balance			blue		Nigeria
Chlore chemistry	blue				Nigeria

Sources of recharge in the Lake Chad basin

There are three sources of recharge in the Lake Tchad basin (fig. 3). UNESCO (1969) carried out the first systematic study of groundwater recharge, using hydrograph records and groundwater dating methods with the isotopes (^{18}O,^{2}H, ^{3}H and ^{14}C) in parts of the Chad basin. Fluctuations of groundwater levels are direct reflections of the conditions that affect the aquifer, such as geology and climate. Near the River, water table fluctuations correspond closely with the dynamic water level of the river. Stable isotope in rainwater for the region has an average value of -4 ‰ $\delta^{18}O$ and -20 ‰ $\delta^{2}H$. Surface water samples from rivers and Lake Chad fall on the evaporation line of this average value (fig. 4).

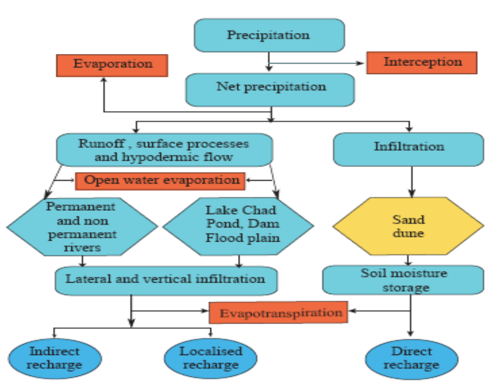

Fig. 3 Sources of recharge in the lake Chad basin

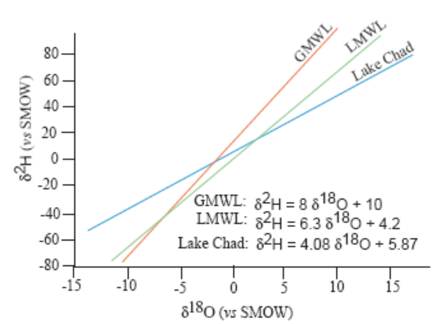

Fig. 4 Deuterium and oxygen-18 content compared to the global meteoric water line (GMWL)
LMWL = local meteoric water line

$\delta^{18}O$ and $\delta^{2}H$ values of groundwater were close to each other. There was evidence of enrichment of heavy isotopes in groundwater due to evaporation. Plotting $\delta^{18}O$ and $\delta^{2}H$, one obtains a linear relationship that follows the equation $\delta^{2}H = 6,3\ \delta^{18}O + 4,2$ typical for water that was subject to kinetic evaporation and therefore exhibits a slope significantly different from that of the global meteoric water line (GMWL: $\delta^{2}H = 8\ \delta^{18}O + 10$). Measured tritium activities indicate that a large variation exists in groundwater age throughout the Quaternary aquifer. Tritium results in groundwater samples gave evidence for ongoing recharge. The shallow aquifers contain more than 50% carbon-14 and the deep aquifers less than about 4% carbon-14. Recharge rates range from 14 - 49 mm/yr, on the basis of unsaturated zone Cl values and rainfall chemistry. Nitrate is generally the contaminant of most concern in the Chad basin.

Conclusions

A critical component to managing water resources is understanding the source of the groundwater that is extracted from a well. In spite of the lack of knowledge on basic hydrogeological parameters of the aquifers involved and piezometric data, environmental isotopes enabled the identification of different types of recharge. The mechanism of the recharge for wells along the Lake Chad is not uniform. To improve the supply guarantee for a given water demand, much more needs to be known about the interactions between groundwater and the surface water (Lake Chad, local ponds), from the hydrodynamic and hydrogeochemical point of view. Some research are planned to overcome these uncertainties.

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