Impact of Human Activity on Groundwater Dynamics (Proceedings of a symposium held during the Sixth IAHS Scientific Assembly at Maastricht, The Netherlands, July 2001). IAHS Publ. no. 269, 2001.

Modelling of nitrate transport in the Mateur aquifer (Tunisia)

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Abstract Groundwater nitrate concentrations in the Mateur aquifer in northern Tunisia have been increasing since the 1980s. The nitrate increase is due to agricultural activities including the increased fertilizer usage. A finite element model of flow and transport was used to evaluate pollutant sources and transport in the aquifer system. The temporal and spatial distributions of the nitrate input were estimated from the economic activities in the region which are conformable to a global nitrate budget calculated for the Mateur plain in this study. Different scenarios of possible management alternatives of agro-economic activities in the region to preserve the quality of the groundwater were evaluated.

Key words groundwater; modelling; nitrate; pollution

INTRODUCTION

Agricultural development, often accompanied by fertilizer use, often results in the contamination of aquifers by nitrogen compounds; this is the case for the Mateur aquifer (Tunisia). The Mateur aquifer, underlying an area of about 450 km^2, is one of the most important aquifers in northern Tunisia, and is partly used as a drinking water supply. High NO_3^- concentrations sometimes exceeding drinking water standards, have been reported for many wells in the area. The objectives of this paper are to identify and quantify the sources of this pollution and to determine the transfer mechanism in the aquifer. The results of this investigation will provide managers with possible management schemes for agro-economic activities in the region to preserve the quality of the groundwater there.

DATA

The plain of Mateur is dominated by intensive agriculture including cereal production and cattle rearing. It is a vast flat plain, crossed by a dense hydrometric network whose outlet is the Ichkeul Lake. Previous studies of the Mateur aquifer system distinguished two levels, one shallow and one deep, that communicate and form one hydrogeological unit. Since 1986, groundwater nitrate concentrations, particularly in the drinking water supply, have increased. Data for the Mateur aquifer system including piezometric levels, porosities, transmissivities, and the flows from a hydrometric network, have been reported elsewhere (ANPE, 1994). Water quality data are only available for the drinking water wells, situated in the central part of the aquifer, near the town of

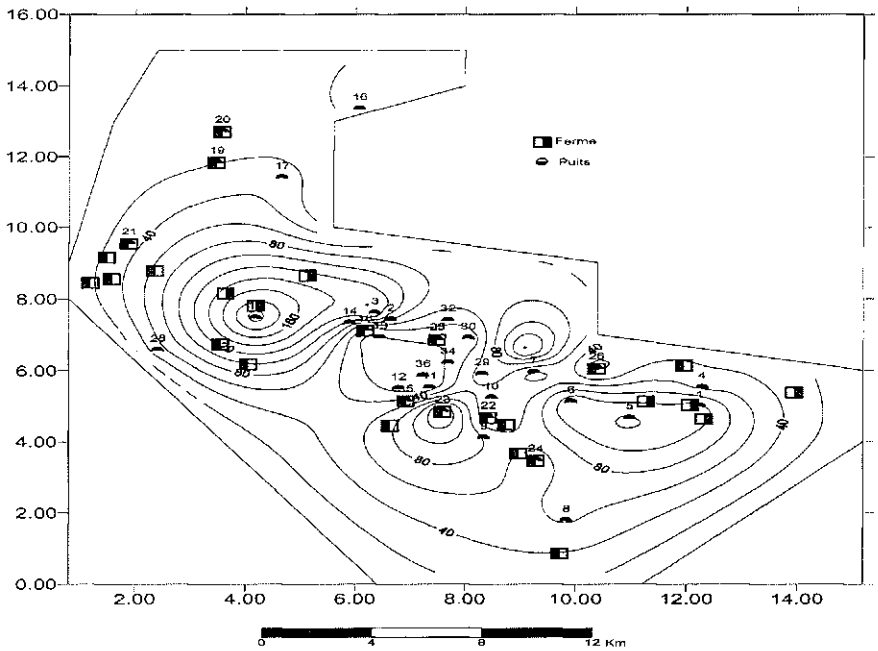


Fig. 1 The spatial distribution of groundwater nitrate concentrations (mg l^{-1}) measured in April 2000.

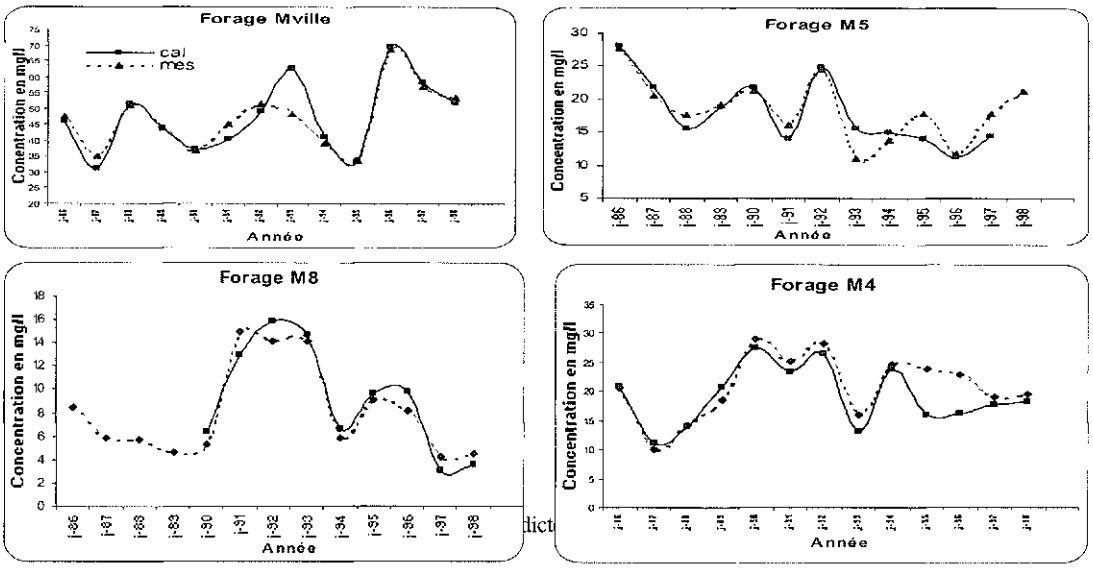
Mateur. Groundwater sampling for water quality analysis was conducted for wells throughout the area to augment the drinking water supply data (Fig. 1). The nitrate concentrations varied markedly ranging from 0 to 240 mg l^{-1}.

METHODOLOGY

A finite-element flow and nitrate transport model was developed for the aquifer to simulate conditions from 1965 to 2000. The nitrate input to the aquifer was calculated and adjusted by soil type, according to the agricultural, industrial and urban activities in the region. The procedure of calibrating the transport module is based on dynamic dispersivity, and nitrate was used as a tracer for the saturated porous media (Gengz, 1991).

RESULTS

Piezometric levels predicted from the flow model correlate with measured piezometric levels in the aquifer. These results allowed us to calculate the water budget and to determine flow velocities in each domain during the period of study. Similarly, the predicted nitrate concentrations correlate with the measured concentrations of the drinking water wells (Fig. 2). These results also provide concentrations in each domain for 2000, the period of sampling. The annual nitrate input to the aquifer and its spatial distribution according to the agro-economical activities were determined from the model.



The inputs were compared to the calculated nitrogen balance for the entire system. The main source of nitrate is the inorganic compounds in fertilizer. The organic contributions of farm sewage and manure, and to lesser extent wastewater, are the secondary source of contamination. The model of nitrate transport in the Mateur aquifer was used to evaluate some scenarios for water-quality restoration, particularly with respect to the identified sources of contamination. These scenarios specifically concern the wastewater treatment, the protection of outcrop hills from pasturage, and the planning of storage areas for manure. The reduction of nitrate fluxes from these sources can lead to an appreciable, but slow, improvement in groundwater quality, with targeted decreases in nitrate concentration after 30 to 120 years.

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