

## ABSTRACT

This study focused on the Thiaroye unconfined sandy aquifer which belongs hydrogeologically to the Senegalese superficial aquifer system. It encompasses an area of about 300 km<sup>2</sup> and extends from Dakar to Kayar in the Northeast. The main groundwater quality problem of the Thiaroye aquifer is the diffusive pollution of nitrogen. High nitrate contents (up to 540 mg/l) which affect the water quality in this aquifer is problematic for the utilisation of this resource for the drinking water supply of Dakar, (capital city of Senegal), in the future.

The work carried out in the study aims to assess the vulnerability of the aquifer system with regard to nitrogen contamination and the influence of the land-use on the nitrate content in the groundwater.

A Geographic Information System (PC ARC/INFO Version 3.4D ESRI 1990) was used to analyse all the data needed for this study.

The hydrogeological investigations were aimed to develop a hydrogeological model for the Thiaroye Quaternary sand aquifer. The hydrogeological model is based on the evaluation of the following input data, which were obtained both from this study and from previous works:

- Classification of production wells, dug wells and piezometers;
- Digital topographic data, based on the topographic information of Dakar, Bargny, Kayar (I.G.N Paris/S.G.N Dakar, 1983);
- Spatial distribution of the piezometric head and temporal evolution of the piezometric head during the last several years;
- Depth of water table;
- Aquifer thickness and aquifer bottom;
- Geohydraulic parameters;
- Hydrochemical data, and nitrogen contamination level;
- The Geographic Information System tool coupled with the empirical formula were used to generate a spatial distribution of the recharge (Fig.60).

Data concerning piezometric heads, geohydraulic parameters and hydrochemical data were statistically and geostatistically analyse for spatialisation.

These data were used as input data for the groundwater water flow model.

The mathematical model was represented by an unconfined aquifer system in a steady state using initial conditions of 1971 and transient state (1971-1997), with 2D linear flow.

The aim of this mathematical model was to verify the parameters defined for the hydrogeological investigation and to predict the piezometric head evolution after the pumping in the production wells (Thiaroye area) is stopped. For this reason the transient state 13 years after stop of pumping was calculated, using mean climatic conditions of the period 1989 - 1997. This period represents relatively dry years compared of the observation period 1985 - 1989 (Fig.69).

This means that the model represents the conservative assumption of relatively low precipitation in the coming years.

The results of the calibration show:

- The heterogeneity of the aquifer system which permeability values range between 0,1 to  $10 \cdot 10^{-4}$  m/s;
- The water budget shows that the aquifer system is recharged by the rainwater infiltration and the output from the system is discharge towards the sea and through evaporation in the "NIAYES" areas. The good fit of the model can be judged by comparing the calculated and observed piezometric head for 1997 (fig.72).
- Stop of pumping in the Thiaroye productions wells gives a maximum rise of 3 m for the piezometric heads at the area between piezometer P3.2 and the Tivaouane Peulh sector (P2-7) in the eastern part of the aquifer. Beyond this area, results show a lowering of the piezometric head due to the rainfall deficit.

To assess the vulnerability of the aquifer system by nitrogen contamination and the influence of the land-use on the nitrate content in the groundwater, a Geographic Information System was used. The analysis is based on the evaluation of the following input data:

- The land-use map (Fig.58), which was produced from a satellite image SPOT (XS+P) dated 23.12.1995. This was used to identify various sources of pollution on the surface. The results clearly indicate the existence of three sources of pollution in the Thiaroye area:

#### **Habitation:**

An urban habitation which is characterised by the agglomeration zones with a population estimated today at more than 1 000 000 inhabitants (population density of 4000 per km<sup>2</sup>). This area includes settlements in Thiaroye, Pikine, Boun, Malika, Yeumbeul, Keur Massar, Parcelles, Guediawaye.

A rural habitation with a less important anthropogenic pressure on the area with a population of about 700 000 inhabitants (population density of 600 per km<sup>2</sup>). This area includes villages and locality from Keur Massar up to Diender.

#### **Street network**

The study indicates that the city street-network have also their own pollution contribution in the aquifer on the agglomeration zone.

#### **Landfill**

The landfills for Dakar city is located in Malika (Mbeubeus), NE of Dakar seems to be also another source of pollution for the aquifer in the area.

Moreover, the Thiaroye area includes uninhabited zones covered by the sand dunes, agricultural areas and the "Niayes" (lowlands with shallow groundwater).

- The soil type and thickness of the unsaturated zone determine the leaching process of nitrates from ground level to the water table. The distribution of the water table depth show that the phreatic aquifer has a depth of less than 6 m in the urban agglomeration zones. The maximum depth is located in the Beer-Thialane and Diender areas with more than 16 m (Fig.77).

The soil types are characterised by Quaternary dunes sands with high permeability. This explains why the infiltration process is fast.

- The piezometric surface of the groundwater allows to determine the direction of the groundwater flow in aquifer.

- The extension of the contamination in the aquifer is shown by the results of hydrochemical analysis. It is the result of the water-quality analysis of representative wells and bore holes. The concentrations of nitrate detected in the Thiaroye aquifer exceed by far the drinking water standards.

The statistical analysis of the nitrate values show an irregular distribution in the aquifer. This is explained by the point sources nature of contamination which are located on the surface. The graphical illustration by Box-plots of the nitrate values (Fig.88) depending on the land-use types give high nitrate concentrations occur in the agglomeration areas. In rural areas the nitrate concentration reach 340 mg/l, in the agglomeration areas up to 540 mg/l.

Because of the generally low nitrate concentrations in the inhabited zones, the groundwater quality is found to meet the drinking water standard. The mean values in the sand dunes areas are 26 mg/l; 12 mg/l in the Niayes zones and 4,5 mg/l in the agricultural zones, where the groundwater is protected by a thick unsaturated zone.

The assessment of the land-use influence on the nitrate contents of the aquifer based on the Geographic Information System allowed to produce a vulnerability map of the Thiaroye aquifer (Fig.89). This map clearly demonstrates that the aquifer system is vulnerable to pollution since there is no real protective cover overlaying the aquifer.

This study demonstrated that a combined approach of the conventional hydrogeological methods and a Geographical Information System investigation helps for a better management of the water resource.