XXXVIII IAH Congress

Groundwater Quality Sustainability
Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University of Silesia Press 2010

abstract id: **216**

topic: **1**
Groundwater quality sustainability

1.4
Groundwater quality and agriculture

title: **Study and modelling non-point agricultural pollution by nitrates in Mateur plain north east of Tunisia**

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keywords: nitrates, unsaturated zone, Mateur, recharge, mechanist model

INTRODUCTION

The groundwater resources constitute significant water resources reserves. In several areas of the world, they are widely exploited to cover the drinking water. Safeguarding groundwater quality constitutes a major preoccupation especially for reasons of public health. The pollution of the aquifers by the nitrogen resulting from fertilization, effluents of farm and waste water discharges constitutes an environmental problem for areas of intense agricultural activity. Prediction of the contamination risks requires a comprehension of the whole processes implied in becoming and circulation of pollutants in the unsaturated zone which constitutes an interface of water exchange, pollutants and micro-organisms between aquifer and the biosphere.

We initially carry out a vulnerability Study of the Mateur plain which is based on DRASTIC (Chebil, 2009) method that constitute an index methods. It is used in order to evaluate the absolute vulnerability on a large scale according to hydrogeologic, climatic and physics parameters of the system. Multiple models were developed in order to simulate the evolution of water flows and transport of nitrogen in the unsaturated zone. The use of a particular model to a hydrogeological basin requires a methodology of division based on the combination of determining characteristics for the processes of transformation and transfer of the nitrogen in the column of soil to aquifer: soil occupation, soil slope, depth of the water level and surface permeability. Simulations will be related then to these homogeneous zones. Methods of interpolation permit to deduce the space distributions of water flows and nitrate which reach the groundwater.

The objective of this study is to quantify non-point agricultural pollution leaving the unsaturated zone and reaching groundwater according to the various activities practised in the area and to the contributions of water. Annual average flows of percolation and its average nitrate concentration are after evaluated.

MATERIALS AND METHODS

Study area

The Mateur zone is situated in North of Tunisia, 50 km of Tunis. It belongs to the large catchment area of Ichkeul which presents a surface of 2600 km^2 (Fig. 1). It is crossed by a dense hydrographic network where the Lake Ichkeul is the outlet system. The textural analysis of the deposits showed a variation between sand and clay. The interannual average precipitation over the period 1996–2008 is 570 mm. The annual average temperature is about 18°C. According to calculations carried out by ET0 Calculator according to method FAO 56 of Penman-Monteith, the potential Evapotranspiration annual medium (ET0) is 1083 mm over the period 1996–2008. The regular chemical analyses carried out by the National Company of Water Exploitation as well as the campaigns realized by Jendoubi (2000) and Talhaoui (2004), indicate that nitrate concentration exceeded standard concentration of 50 mg/l.

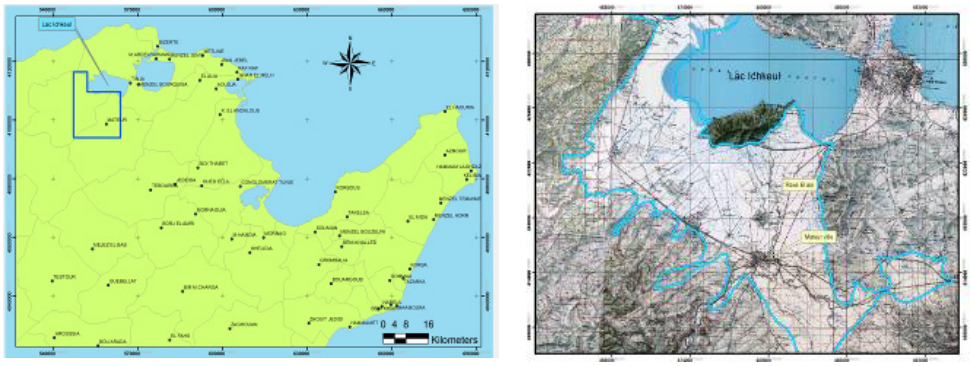

Figure 1. The Mateur zone.

Land use

The study zone is known by an intense agricultural activity because of the fertility of its grounds as well as the abundance of the farm equipment. The mainly cultures practised are: cereals, garden cultures and olives. The total cultivated surface knows a great growth with 51.900 ha in 2000 and 767568 ha in 2007. The intensive cattle's farming is also largely practised which concentrate significant numbers of animals and grazing zones identified by the regional authorities. Discharges of farms are estimated at 120 Kg/ha/an (Jendoubi, 2000).

MODEL DESCRIPTION

LEACHM (Leaching Estimation Chemistry Model) is a deterministic model (Hutson, 2003). It describes physical and chemical processes of water transfer and nitrogen and pesticides transformation in soil in agricultural area. LEACHM Model consists of five sub-models; one of them is LEACHN model which specially simulated for nitrogen transformation. This model has already been extensively applied to different environments (Lotse et al., 1992; Johnson et al., 1999; Sogbedji et al., 2001; Ibnoussina, 2007). This model can be used in either laboratory or under field conditions. It uses a finite-difference form of Richards' equation to predict water contents dynamics and simulate the nitrogen cycle which concern different processes such us: mineralization, Denitrification and uptake root. The boundary conditions represented by precipitations, irrigation and evapotranspiration for the water flux and nitrogen input in the form of fertilizations or rejections for the transport equations. This model was used in order to follow the effects of the intensive use of fertilizer on the groundwater contamination (Singh et al., 2001).

SPATIAL ANALYSIS

Modelling must be carried out on a homogeneous entity on the horizontal level. The application of LEACHM model on a heterogeneous watershed requires its division into homogeneous sectors.

The plain of Mateur is characterized by a wide range of profiles developed at different levels (soil texture, various cultivation practices that are increasing in this area one year to another). This condition makes difficult any attempt to estimate the various terms of nitrogen balance across the entire study zone. For that purpose, the adopted approach in this study is similar to

that established by Gnouma (2006) which involves the integration of maps: land use, depth of groundwater, permeability of surface and the slope of the soil. Each one of these parameters is subdivided into three classes of values. Each unit is characterized by a single type of agricultural practice, permeability, depth of the water and slope. Dividing the study area leads to homogeneous units or areas, then the model LEACHM can be used in each area so defined. The selection of profiles is made on the basis the DRASTIC index (Fig. 3) and the combination map of parameters (Fig. 4). For each profile we obtained the flow of water percolation and their nitrate concentration over time.

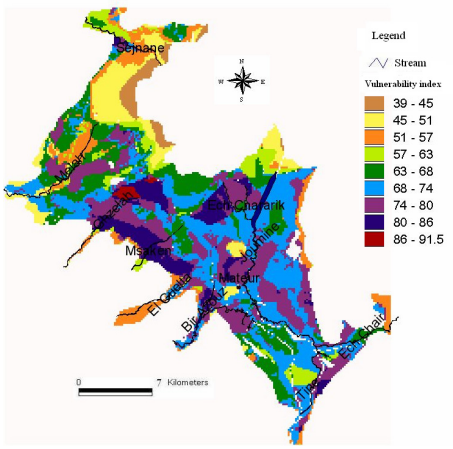

Figure 2. Map of class of vulnerability.

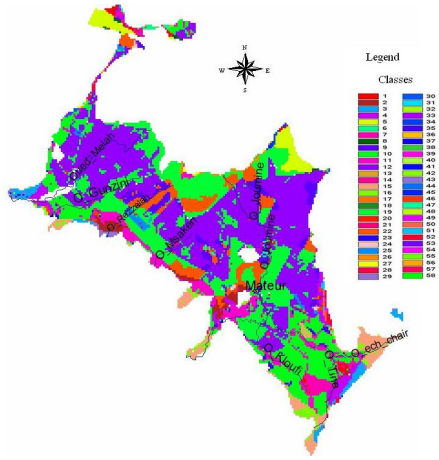

Figure 3. Map of class of homogeneous areas.

WATER FLUX PERCOLATION AND NITRATE LEACHING INTO THE AQUIFER OF THE PLAIN MATEUR

The distribution of recharge flux map (Fig. 4) shows that the most permeable zones allow transfer of pollutants through the unsaturated zone. The study results show that annual recharge rate increases due mainly soil physical properties (texture, permeability ...) since we work with average climate conditions. More soil is permeable more concentration of nitrate is very important. The high recharge areas may also indicate that the groundwater is subjected to a very significant contamination by nitrates. The highest water flux percolation reach 72 mm/year for an average annual rainfall of 570 mm/year for fine textured soils and high permeability. The map shows clearly that the maximum quantities of percolated water are from areas associated with fine textured soils and high hydraulic conductivities and low flux values correspond to clay areas.

Similarly, the map of nitrate distribution shows the average annual nitrate leaving the unsaturated zone and reaching groundwater (Fig. 5). Nitrate concentrations exceed the potability thresholds, which is 50 mg/l. The highest values were observed in areas of continuous release of farms with fertilizer application and sandy soil. Areas in north of Mateur region are characterized by nitrate concentrations around 247 mg/l. The intensive use of nitrogen fertilizers, the very high permeability sandstone areas and the proximity depth of water level allow these high levels of nitrate. In the southern region of Mateur, nitrate concentrations are low because the vadose zone is very clay and the level of water is very deep.

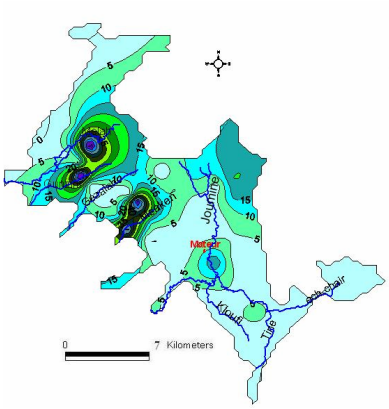

Figure 3. Map of groundwater recharge.

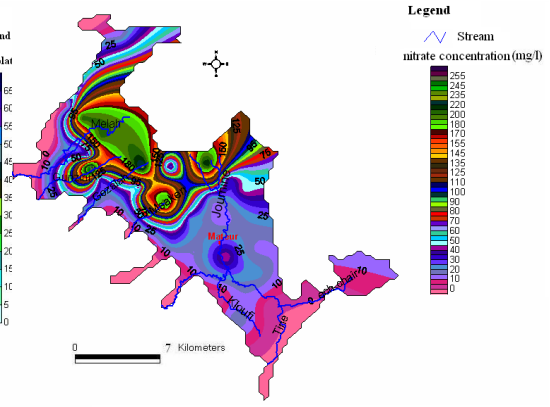

Figure 4. Map of nitrate concentration.

CONCLUSION

Understanding the impact of contamination by nitrate is essential to ensure better management of water quality intended for human consumption. Several models have been proposed to quantify the transport pollutants derived from agriculture in unsaturated soils. The development of vulnerabilities maps by the DRASTIC method constitutes an important support planning and decision making for the determination of the most vulnerable and sensitive to pollution and the information necessary to build a network of surveillance for the protection of the aquifer. The methodology followed in this work is to simulate in soil profiles the water flux to the groundwater and their nitrate levels using the model LEACHM. Given that the distribution of water flux percolation and their nitrate levels over time is highly variable, we adopted the data of precipitation and evapotranspiration averaged over time with an average hydrological year.

Applying such a model in a watershed requires as a preliminary, it's zoning in homogeneous simulations area by carrying out collection of thematic maps. These generate the mapping of cartographic units in which features profiles of soil types have been identified. On each one of these profiles, we simulate unsaturated flux and reactive transfer of nitrogen in a daily time step for an average hydrological year. Spatial integration of these results enabled us to establish a recharge map. The water flux percolation to the groundwater reach 72.2 mm/year, or an average recharge rate of about 7.9% for an average interannual rainfall of 570 mm/year. The average concentrations of nitrates in recharge flows exceed 200 mg/l. The most vulnerable areas are characterized by a fine texture and continuous discharges from farms with fertilizer application. These distributions of flow and their nitrate levels will make it possible to calibrate a hydrodynamic model and transport of nitrate in groundwater of Mateur in steady state.

REFERENCES

Chebil M., 2009: *Evaluation of vulnerability and risk of agricultural pollution of Mateur groundwater.* Master Modeling in Hydraulic and Environment, National Engineers School of Tunis, 83p. (English Translation).

Hutson J.L., 2003: *LEACHM: Leaching Estimation and Chemistry Model: A process-based model of water and solute movement, transformations, plant uptake and chemical reactions in the unsaturated zone.* Version 3.0, Research Series No. 93-3, Cornell University, 146p.

Ibnoussina M., 2007: *Experimentation and modeling the water flow and the nitrate leaching in a sandy soil.* Application aux sols de Mnasra, Physic Phd. Faculty of Science of Kenitra. 180p. (English Translation).

Jendoubi A., 2004: *Modelling transfer of nitrates in Mateur aquifer.* Master Modeling in Hydraulic and Environment, National Engineers School of Tunis. 111p. (English Translation).

Johnson A.D., Cabrera M.L., McCracken D.V., Radcliffe D.E., 1999: *LEACHN Simulations of Nitrogen Dynamics and Water Drainage in an Ultisol.* Agronomy Journal, Vol. 91, pp. 606–797.

Lotse E.G., Jabro J.D., Simmons K.E., Baker D.E., 1992: *Simulation of nitrogen dynamics and leaching from arable soils.* J. Contaminant Hydrology, 10, pp. 183–196.

Singh K.G., Sondhi S.K., 2001: *Validation of Fertilizer Nitrogen Model during Crop Production.* J. agric. Engng Res., 78 (3), pp. 317–324.

Sogbedji J.M., Van Es H.M., Hutson J.L., Geohring L.D., 2001: *N fate and transport under variable cropping history and fertilizer rate on loamy sand and clay loam soils.* Plant and Soil 229, pp. 71–82.

Talhaoui W., 2004: *Test of modeling the groundwater of Mateur. Optimisation of their resources.* Master of geology. Faculty of Sciences of Bizerte. 130p. (English translation).

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2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0