STUDY OF THE IMPACT OF INDUSTRIAL DISCHARGES ON SURFACE WATER AND GROUNDWATER IN THE AREA OF ANNABA.

N.Bougherira [1] – A.Hani [1] – D. Nechem [2] - N.Haied [3] – Larbi Djabri [1]

[1] *Nabil Bougherira, Laboratory REDD - Badji-Mokhtar Annaba University. Algeria. E-mail:* nabilbough@gmail.com
[1]*Azzedine Hani, Laboratory REDD - Badji-Mokhtar Annaba University. Algeria E-mail:* haniazzedine@yahoo.fr
[2] *Dounia Nechem, - Badji-Mokhtar Annaba University. Algeria E-mail :* ndannaba@gmail.com
[3]*Nadjib Haied, Department of Planning, Ziane Achour University - Djelfa. Algeria E-mail: nhaied@yahoo.fr*
[1]*Larbi Djabri, Laboratory REDD - Badji-Mokhtar Annaba University. Algeria E-mail: djabri_larbi@yahoo.fr*

ABSTRACT

The characterization of a hydrologically complex contaminated site bordering the Meboudja river (Annaba, Algeria) was undertaken by investigating surface water and groundwater affected by Number of industrial rejections have been established during 1999-2009 in the El-Hadjar Industrial Development Area in the Annaba region, North-East of Algeria. The treated and untreated effluents from the industries are being discharged in Meboudja wadi. Groundwater level and water quality monitoring was carried out during 1999 and 2009 in El-Hadjar and its environs. Surface water samples were also analyzed for the water quality. The groundwater shows a high electric conductivity (more than 1000 cm-1 with a maximum exceeding 6000 µScm-1), a high chloride content (with a maximum exceeding 1400 mgl-1), and a high sodium concentration (maximum = 730 mgl-1) are observed for the wells located down gradient and near the industrial rejections. Also, high iron and manganese concentrations are observed in these wells. The Meboudja is acting as a diffuse source of contaminations all along its course. Aquifer parameters were estimated by carrying out pumpings test at a number of wells. Groundwater flow and mass transport models were prepared using visual MODFLOW software. The extent of migration of contaminants from the Meboudja and other streams has been assessed for 11 years (1999-2009). The stream-aquifer interaction was found to be responsible for faster migration of contaminants in the over-exploited area east of the Seybouse.

Keywords: Steel industry, contaminant migration, industrial pollution, mass transport modelling, stream-aquifer interaction, TDS concentration.

1 INTRODUCTION

Increase of waste production is correlated with economical and demographical development. While life improvement expected, such development also leads to negative effects on the environment and economy of many countries. Demographical development and intensification of the economical activities in Algeria are accompanied by an increase in solid waste production (Kherici, 1993; Djabri, 1996; Debièche et al., 2003).

This uncontrolled dumping has negative effects that are clearly identified such as nauseous smells, smoke generation, water and soil pollution (Debièche et al., 2003, Hani, 2003).

The industrial effluents contain appreciable amounts of both inorganic and organic chemicals and their bye-products. Most of industries are in small scale sector and are not having any sewer lines. Even today most of them don't have proper wastewater treatment plants and they discharge industrial effluents in unlined channels and streams and thereby causing enormous contamination of air, water and soil. As a result, the highly coloured and toxic chemical effluents join the river of Meboudja, which is a left-side tributary of Seybous River, polluting surface and groundwater.

The degree of contamination has been so intense that in some parts the environment has become unsuitable for human life. Traditionally, people of the lower Seybous plain are an agricultural community. None of the industrial units took any measures for safe disposal of industrial effluents till 2000. Annaba was no longer like 20 years ago. Experts attribute the present situation to both lack of planning and mindless sitting of industries (Japanese Agency of International Office of Survey for the Countryside Development, in Zenati, 1999).

In order to find out the impact of these effluents on the river water and groundwater quality, a monthly water monitoring chemistry was performed in the river and in the water catchment, situated lower Seybous plain.

In the present research, groundwater monitoring has been taken up for effective assessment through understanding of hydrogeology, geology and water-chemistry of the watershed. The collected basic data is used for the preparation of the groundwater flow and mass transport model for quantitative assessment of contaminant migration impact on the watershed. To find out the groundwater velocity distribution is used in order to analyze advectif and dispersive transport to settle on contaminant migration in the area.

2 STUDY AREA

The studied area is situated in the lower Seybous plain (NE Algeria) upstream of Meboudja river (Fig. 1). The northern limit of the zone is constituted by the metamorphic basement, whereas the other limits are open limits which are in continuity with the shallow aquifer of the low-lying Seybous plain.

River Meboudja is characterized by a permanent flow in winter. Its alimentation comes from rain waters, and drainage of the lake Fetzara (the discharge reaches 16 m^3s^{-1}). During the summer, the water inflows are mainly the lake outputs (the flow rate ranges between 1 and 5 m^3s^{-1}). The river receives also urban contributions upstream, such as domestic sewage waters. The aquifer reservoir is developed on a clayey substratum. The aquifer formations are represented by 70 loamy sand and 30 clays (Japanese Agency of International Office of Survey for the Countryside Development, in Zenati, 1999). The average permeability ranges between 10^{-3} and 10^{-4} m s^{-1}.

The Mediterranean climate is of type with an annual rainfall of 650 mm, a mean temperature of 18°C and high atmospheric humidity. The dominating wind direction (Northwest-Southeast) blows from the studied area towards the region of Drean. The effective infiltration is about 15% of the total rainfall that is 100mm per year, which infiltrates through waste, soil and finally to the ground water (Hani, 2003, Debièche, 2002).

Some of the wells situated about 400-500 m away laterally from the **z= 09m** (Meboudja River) in El-Hadjar village are not presently in use because of the contamination. The TDS concentration of groundwater has reached about 4000 mg L^{-1}.

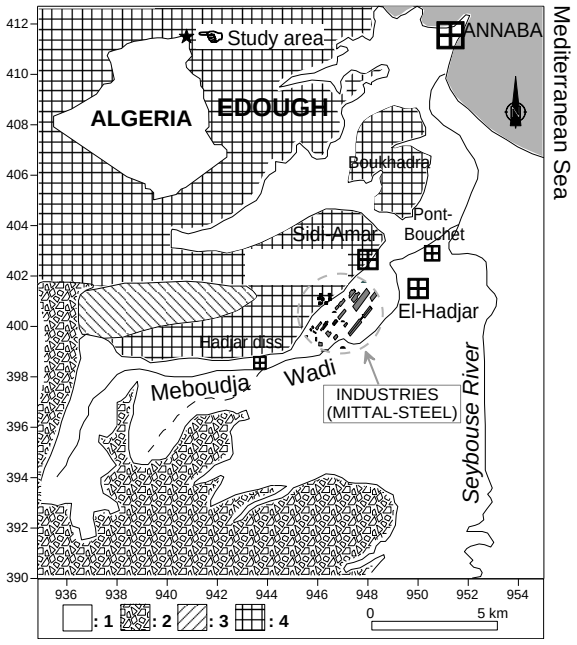

Figure 1. Location map of study area: 1: Undifferentiated Quaternary, 2: Ancient alluvium, 3: Numidian sandstone or clay, 4: Metamorphic formation.

3 MATERIAL AND METHODS

Many monthly surveys of the piezometric level and geochemical analysis have been monitored. The analyses are carried out on a network of 30 wells in the plain of Meboudja (Fig. 3). Some sampled wells are used by the neighbouring population for daily drinking, irrigation and animal alimentation (case of P2). The grounds were taken according to a direction south-north.

The temperature (T), electrical conductivity (EC) and pH were measured in situ using a multiparameter WTW set (Multiline P3 PH/LF SET), an Ox meter (WTW) with an oxygen probe (Cell Ox 325) for the measurement of dissolved oxygen. The heavy metals (Fe, Zn, Mn, Cu, Cd, and Cr) were determined using atomic absorption spectrophotometer (Unicam 929 AA Spectrometer).

In the present study, groundwater monitoring has been taken up for effective assessment through understanding of hydrogeology, geology and water-chemistry of the watershed. The collected basic data is used for the preparation of the groundwater flow and mass transport model for quantitative assessment of impact of contaminant migration in the watershed. To determine the groundwater velocity distribution is used to analyze advectif and dispersive transport to determine contaminant migration in the area.

4 RESULTS AND DISCUSSION:

4.1 Water Chemistry

Water samples collected from bore wells, dug wells and surface water bodies at 50 locations were analyzed for ionic concentration, pH and total dissolved solids (TDS). The observed surface water TDS in downstream is ranging from (4150 mg L^{-1}) near El-Hadjar to (2970 mg L^{-1}) in upward (Fig.4). The impact of pollution due to effluent discharge from industries located around El-Hadjar resulted in a decrease of TDS concentration of groundwater to (2180mg L^{-1}) as one can see in the TDS concentration map of (fig.3).

To put in evidence the impact of the interaction river water ground water on the quality of the underground waters one followed monthly EH; pH; Fe(T); Mn^{+2} was realized on the set of the wells picking the alluvial ground water . The drawings out of water for analyses were also carried out on the waters of Meboudja River**.**

4.2 Origin of the contents in iron and manganese in the waters of Meboudja River

The carried out analyses on the industrial and urban rejections make existence in the iron and manganese appear it to elevated contents. Both elements of common origin, is the factory Mittal Steel Arcelor's acid rejections. The spatial evolution of the elements (Fe (T) Mn2+) in the waters of the river was analyzed for the month of June, where the rushes are very weaklings, the values of pH (8,82 - 8,92) and E_H (115 - 140 mV) are stable. The raise of the concentrations ***iron*** And some ***manganese*** at the level three stations (M_2, M_3 and M_4) are told the industrial rejections of wealthy Mittal-steel Arcelor elements ferric and manganese steel. The weak concentrations under shape dissolute, are told the basic middle conditions (pH 8,82 at 8,92). In this context, the ions precipitate sediments at the level under intricate shapes (hydroxides and carbonates.) The steadiness of the contents in iron and in manganese on the three stations, comes of the effect of the steadiness of pH (8,82 at 8,92) and E_H (355 at 362 mV) pointing out that the iron and the manganese exist in identical to the level proportion of the three stations. No contribution in iron and in manganese is recorded at the level of the stations M3 and M4, situated however near of industrial perimeters.

At the level of the station S_1, the contents in iron and in manganese diminish brutally as a result of the collaborative effect of the dilution by the waters of the river Seybous and the chemical rush of the iron and of the manganese in oxidizing middle (S_1 3 mg.l^{-1} of O_2.)

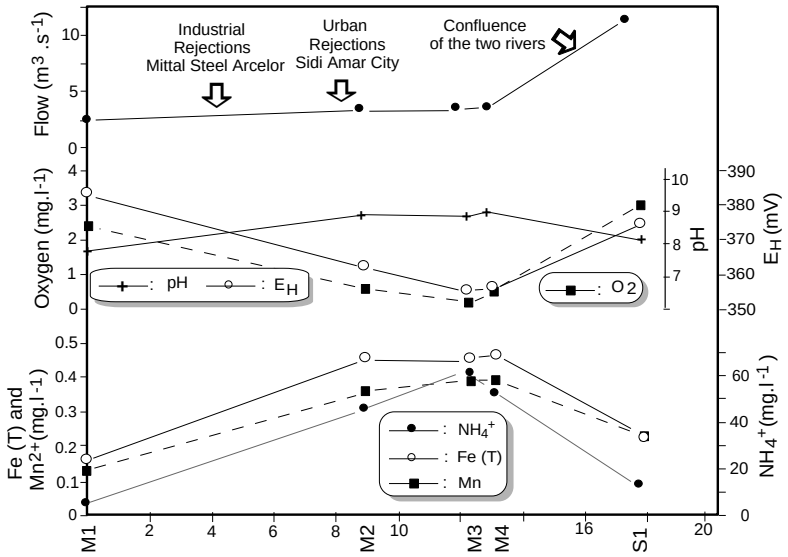

Figure 2. Evolution in time of the iron and manganese content of the alluvial aquifer of the Meboudja.

4.3 Study of the contents in iron and manganese in the groundwater

During the period of the high waters, the levels of water in the ground water and of the river are elevated following the strong rains month of January. The flow is directed to the aquifer toward the river except for the wells in exploitation situated in border of the river (Case of the well P2)Where the flow is aided river towards the aquifer. The evolution during the low waters is characterized by a decrease of the level of water in the river and in the aquifer with the same direction of passing (aquifer towards the river.) The noticing of the level of the river which passes to the upper of that in the aquifer starting with the month October drove at the inversion of the direction of flow, the river feeds the aquifer.

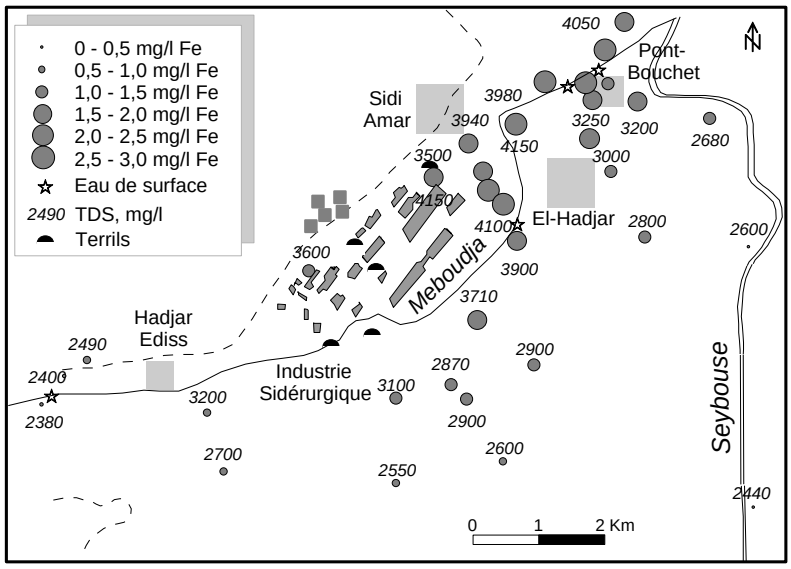

Figure 3. total dissolved salts (TDS) and iron in surface water and groundwater in the plain of Meboudja (mg L-1)

5 Groundwater Flow Model

The simulated model domain consists of 40 rows and 40 columns and 1 layer covering an area of 8000 x 8000 m. The superficial aquifer mostly consists of a 10-15 m thick alluvium along the Meboudja. The simulated vertical section has a maximum thickness of 15 m. The groundwater recharge at the rate of 100 mm yr^{-1} has been simulated in the top layer. Continuous seepage from the

Meboudja stream was simulated as additional recharge in the model. The first stage of modeling is flow simulation for computation of hydraulic head distribution. The distribution of hydraulic head and hence the velocity field is unaffected by migration of plume because density and viscosity of contaminated groundwater is nearly the same as uncontaminated water in the area. The flow equation was therefore, first solved independently of the mass transport equation. Further, water level observations in the area indicate that hydraulic gradients do not change significantly with time. Thus groundwater flow was assumed to be in a steady state and the groundwater heads were computed by visual MODFLOW (Guiger and Frantz, 1996) using Slice Successive Over Relaxation (SSOR) package (McDonald and Harbaugh, 1988). The flow model was calibrated by adjusting several parameters within a narrow range of values until a best fit was obtained between observed data and simulated results. The accuracy of the computed water levels (Fig.4) was judged by computing mean error, mean absolute error and root mean squared error computed for 15 observation wells. The calculated mean error, mean absolute error and root mean squared error under steady state condition is –0.14, 3.2 and 3.6 m, respectively.

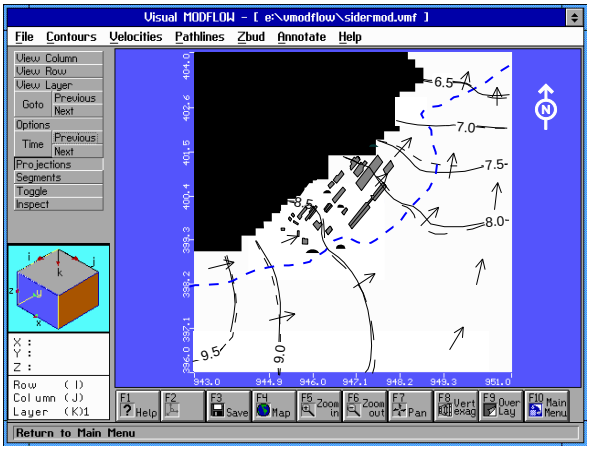

Figure 4. Distribution of hydraulic heads. Dashed lines, simulated; continuous lines, measured. Contour interval, 0.5 m.

6 Mass Transport Model

Mass transport in three dimensions (MT3D) is a computer model for simulation of advection, dispersion and chemical reactions of contaminants in three-dimensional groundwater flow systems (Zheng, 1990). The model is used in conjunction with a block-centred finite difference flow model MODFLOW. Dispersion was accounted for the particle in motion by adding to the deterministic motion a random component, which is a function of dispersivities. The mean concentration for each grid block was calculated as the sum of the mass carried by all the particles located in a given block divided by the total volume of water in the block. The values of dispersivity in longitudinal and two transverse directions (Y and Z) were assumed to be 10, 1 and 0.1 m, respectively, and the values were taken from the literature (Kimbrough et al., 1999; Domenico and Schwartz, 1990; Tevissen, 1993). The tendency for α_L to be about 10 times larger than α_{TH} and for α_{TZ} to be much smaller than either of them is in line with the concentrations observed in the area. The initial TDS concentration assigned in the rest of the area is about **2180** mg l^{-1}. The relatively smooth decline of TDS concentration away from the Meboudja suggests a relatively constant rate of loading. Thus a constant TDS concentration at different nodes on the Meboudja was assigned varying from **4180** mg l^{-1} at source (Mittal steel) near the Sidi Amar and **2970** mg l^{-1} away from the Mittal steel at about 7 km downstream of the Meboudja.

The extent of contaminant migration from the Meboudja stream could be seen by computed iso-concentration of TDS contours of transport model for the period of 1999-2009. The contaminant migration was found expending up to 600 m from the Meboudja during the last **11** years (Fig.5). Inaccuracies in the simulated flow field could have existed, which produced somewhat more divergent flow pattern from what actually exists. Because we have given uniform pumping rates for the wells and diffuse source concentration at all nodes of the Meboudja, this problem could be related to the complex interaction between groundwater and surface water.

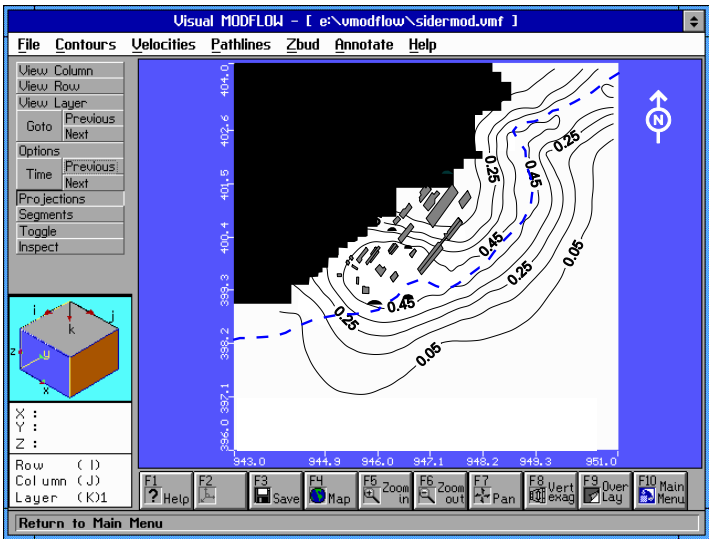

Figure 5. Computed TDS concentration (mg L^{-1}) of groundwater in Meboudja plain.

CONCLUSION

Here a case study of groundwater/surface water pollution due to uncontrolled industrial effluent discharges and its environmental impact on groundwater regime is presented. Groundwater pollution extends laterally 500-600 m from the Meboudja, in which initial pollutants load, in the alluvial areas covering villages Sidi-Amar and El-Hadjar. The extension of pollution is due to heavy pumping for irrigation, resulting in induced seepage from Meboudja due to stream aquifer interaction, which in turn carries surface water effluent to the groundwater regime. The contaminated groundwater is being exploited for agriculture and industrial purposes in the absence of major surface water sources in the area. The modeling study has helped to gain a better insight of the hydrogeologic set up and assessment of contaminant migration.

The untreated effluents emerging from the industries must be monitored for maintaining the standards prescribed for TDS concentration by the environment inspection for various industries in the region. The present study provided a base line data for assessment of contamination in the El-Hadjar area. For reduction of the stream aquifer interaction, the pumping around the Meboudja wadi should be reduced. Periodical monitoring of the water quality has to continued to check the rise in TDS concentrations of groundwater.

REFERENCES

Bear J.: 1972, *Dynamics of Fluids in Porous Media*, New York, American Elsevier, pp. 764.

Debièche T.H., Mania J. and Mudry J. : 2003, Pollution d'une nappe alluviale par le chrome et l'étain à partir d'un stockage de résidus métallurgiques: Application à la basse plaine de la Seybouse, Nord-Est Algérien. Africa Geosciences Review, Vol. 8, N°4, pp. 425-435, 2003.

Djabri L. : 1996, Mécanismes de la pollution et vulnérabilité des eaux de la Seybouse. Origines géologiques, industrielles, agricoles et urbaines. Th. Doct. Es-Sciences, Univ. Annaba, 261p.

Domenico P. A. and Schwartz F.W.: 1990, *Physical and Chemical Hydrogeology*, John Wiley & Sons, U.S.A., pp. 824.

Grove D.B. and Stollenwerk K.G.: 1984, *Computer Model of One-Dimensional Equilibrium Controlled Sorption Processes*, U.S. Geol. Survey Ressources Investigations Report 84-4059, pp. 58.

Guiger N. and Frantz T.: 1996, *Visual MODFLOW: Users Guide, Waterloo Hydrogeologic*, Waterloo, Ontario, Canada.

Hani A. : 2003, Analyse méthodologique de la structure et des processus anthropiques : application aux ressources en eau d'un bassin côtier méditerranéen. Th. Doct. Es-Sciences, Univ. Annaba, 214p.

Javandel I., Doughty C. and Tsang C.F.: 1984, *Groundwater Transport: Handbook of Mathematical Models*, American Geophysical Union, Water Ressources Monograph 10, pp. 228.

Kherici N. : 1993, Vulnérabilité à la pollution chimique des eaux souterraines d'un système de nappes superposées en milieu industriel et agricole (Annaba- la Maffragh, NE Algérien). Th. Doct. Es-Sciences, Univ. Annaba, 170p.

Kimbrough D.E., Cohen Y., Winer A.M., Creelman L., Mabuni, C.: 1999, Acritical assessment of chromium in the environment. Critical Review in Environmental Science and Technology, 29, 1, 1-46.

Louhi A. : 1996, Pollution des eaux et sols. Cas de la région de Annaba. Etude des interférences et dosage Al, Fe, Zn, Ni, Cr, Pb, Sn et Hg par spectrométrie d'émission Plasma-ARC (DCP-AES), absorption atomique (SAA) et spectrophotométrie UV/VIS. Th. Doct. Es-Sciences, Univ. Annaba, 167p.

McDonald J. M. and Harbaugh A.W.: 1988, A Modular Three-Dimensional Finite-Difference Groundwater Flow Model, Techniques of Water Ressources Investigations of the U.S. Geological Survey Book, 6, pp. 586.

Tevissen E. : 1993, Méthodologie d'étude et modélisation du transport de solutés en milieux poreux naturels. Application à la migration du chrome dans la nappe alluviale du Drac (Isère). Th. Doct. INPL, Nancy, 150p.

Zenati N. : 1999, Relation nappe-lac, confirmation par l'hydrochimie. Cas de la nappe superficielle de la plaine Ouest d'El-Hadjar, lac Fetzara, N.E. Algérien. Mémoire Magister, Univ. Annaba, 148p.

Zheng C.: 1990, MT3D, a Modular three-dimensional transport model for simulation of advection, dispersion and chemical reactions of contaminants in groundwater system prepared for the U.S. Environmental Protection Agency.