

# Hydrochemical Evolution of the Chalk Aquifer through the Coal Mine Basin of the Nord-Pas-de Calais Region (France)

Frédéric Barrez, Erick Carlier, Jean-Philippe Carlier, Isam Shahrouf

*Department of Civil Engineering, Laboratory of Mechanic of Lille (LML, UMR CNRS 8107), Polytech'Lille, University of Sciences and Technologies of Lille, Avenue Paul Langevin, F-59655 Villeneuve d'Ascq, France  
E-mail: Frederic.barrez@Polytech-lille.fr, tel.: +33-328767309, fax: +33-328767331*

## Abstract

The coal basin of the Nord-Pas-de-Calais region (France) shows a very strong deterioration of the Chalk aquifer quality. The water chemistry is strongly influenced by coal mine tips which release sulphate in the aquifer. Moreover, chalk aquifer can also be polluted by nitrate brought by agricultural practices or sewages and heavy metals brought by industrial activities. In order to improve knowledge on the chemical interactions, sampling according to depth of the groundwater is undertaken. The low-flow sampling and the profiles of the in-situ physicochemical parameters allow the observation of vertical heterogeneities of the aquifer.

## Introduction

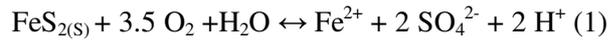
The Chalk aquifer provides the major part of the water resources in the Nord-Pas-de-Calais region. Many factors influence the quality of the aquifer: petrochemical and siderurgical industries, the coal mine tips (vestiges of the mining activities), road and channels infrastructures, agriculture, urbanization...etc. Its protection constitutes a capital stake for the economic development of the area. There are various types of pollution and it appears often difficult to distinguish the sources from them. Recent studies show that the aquifer is especially polluted by sulphates (Denimal et al, 2002) and nickel (Vallée, 1999). The multiplicity of the sources of emission and the types of pollutant implies a better management of the monitoring of the network of piezometers but also an increased knowledge of the hydrodynamic and hydrochemistry of the aquifer. The complexity of the chemical processes and the flow systems lead us today to integrate the "depth" dimension.

The aim of the present study is to observe the evolution of the water chemistry through the coal mine basin and to check the contribution and the relevance of a rapid sampling technique according to depth at a local scale. The groundwater is sampled by low-flow purging technique every 4-5 meters to estimate the vertical contaminant distributions and the results are deferred in "snap shots" of groundwater quality or hydrochemical profiles according to depth. The dataset obtained by this technique in different environmental conditions and for different sampling periods will make it possible to improve comprehension of the variations of hydrochemistry according to depth and the evolution of contaminant plume. The future principal uses of these results are to perform the water quality of pumping water by optimizing the location of the pump in the borehole and to perform the monitoring of industrial sites by a suitable sampling.

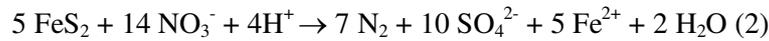
## Study area and impacts of coal mine tips

The study area corresponds to a part of coal mine district in the Nord-Pas-de-Calais region. It is located at the unconfined-confined boundary of the Chalk aquifer. The aquifer is unconfined in the South and the West and becomes gradually confined under Louvil clay at the North-East (Fig. 1). The limit of confined zone approximately corresponds to the Deûle canal. In the southern and western zones of the area, Chalk outcrops, this makes it particularly vulnerable to pollution due to the lack of impermeable cover. The water flow directions (arrows on Fig. 1) are generally South/North in the western part of the study area and South-West/North-East in the eastern part. A cone of depression is located in the North-East corresponding to a significant pumping rate for an industry.

The water of this area can sometimes be characterized by a strong sulphate mineralization. Previous work has pointed out several possible sources of sulphate (Bernard, 1979; Droz, 1985; Denimal et al., 2002) like the dissolution of gypsum contained in the tertiary formations and the sulphates of anthropogenic origin linked to wastewater discharge and/or agricultural practices. But one of the major sources of sulphate is brought by the coal mine tips (triangles on Fig. 1) mainly composed of siltstone. The  $\delta^{34}\text{S}$  study of sulphate (Denimal et al., 2002) showed that these coal mine tips could release great quantities of sulphate downward to the Chalk aquifer by the oxidation of the pyrite (reaction 1) contained by the Carboniferous siltstone:

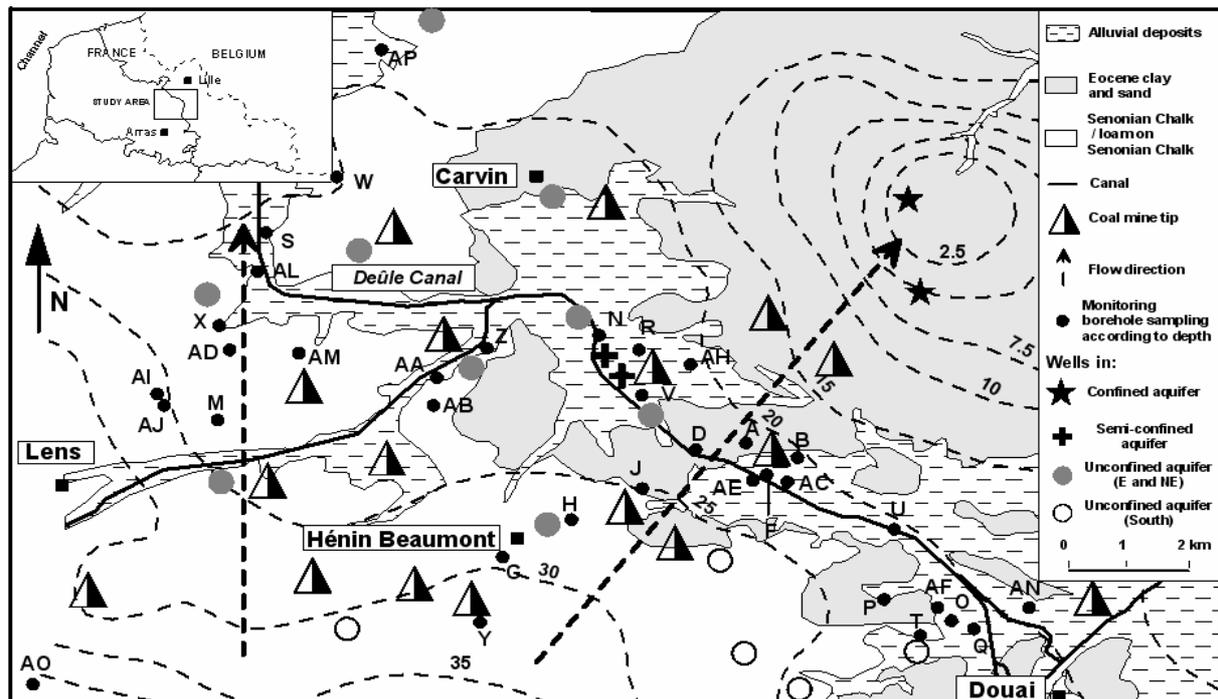


The concentrations of sulphate can easily exceed 2 g/l downstream of coal mine tips. Sometimes, the pyrite can also lead to a denitrification (reaction 2) in acid conditions (Pauwels and Talbo, 2004):



This last phenomenon could be implied in the reduction of the nitrate concentration downstream of some coal mine tips (localised at the unconfined zone of aquifer). Denimal et al. (2002) also showed that there was no significant metal contribution by coal mine tips.

**Figure 1:** Location of the monitoring boreholes and wells. Generalised piezometric levels (April 2001) above mean sea level are represented by dotted lines.

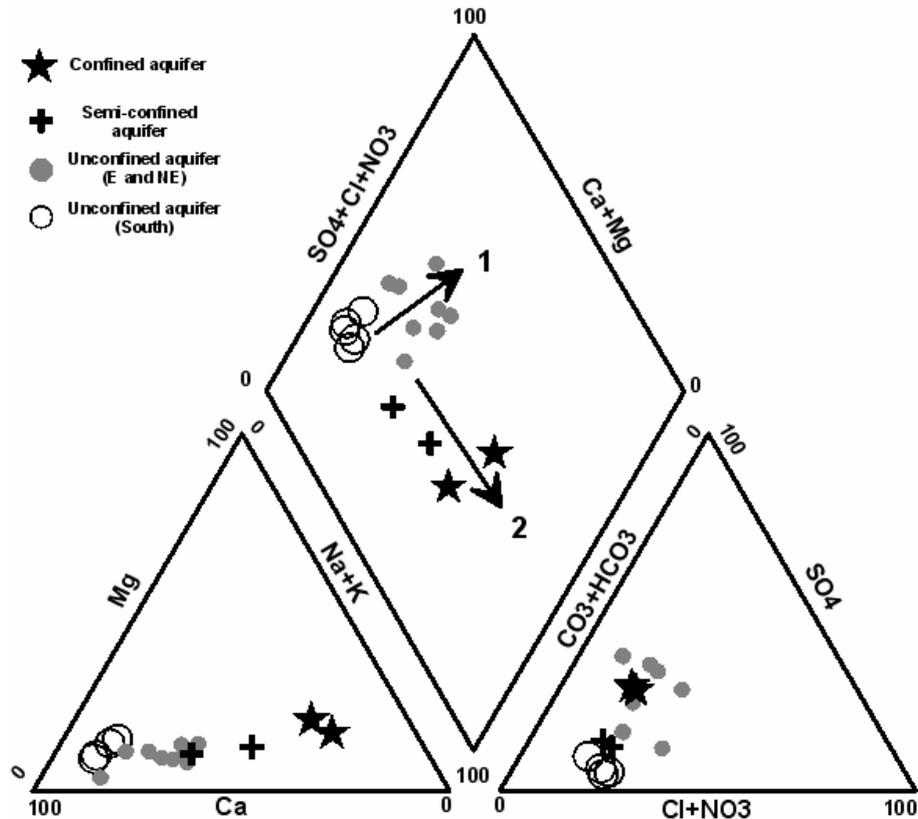


### Hydrochemical characterization of Chalk aquifer

To define the hydrochemical background, the chemical results from wells of water supply and some monitoring boreholes (Fig. 1) are plotted on a Piper diagram (Fig. 2). These measurements exclusively come from not polluted wells and are representative of groundwater on a local scale. Four chemical water types appear:

- Calcium bicarbonate-rich waters at the south (O). This area constitutes the south limit of coal mine basin. It is characterised by agricultural practices and groundwater are sometimes polluted by nitrates.
- Calcium sulphate-rich waters through the coal mine basin at the West and the North-West (●). The water is strongly influenced by the release of sulphate coming from coal mine tips.
- Chemically intermediate waters (+) between calcium bicarbonate-rich waters and sodium / potassium carbonate-rich waters at the transition between unconfined / confined aquifer.
- Sodium / potassium carbonate-rich waters (★) at the North-East. In the confined area, the increase of water-rock contact produces a progressive recrystallization of calcite. Cationic exchanges with the substratum can explain that concentration of calcium decreases whilst concentration of sodium increases. The increase of concentration of potassium could be due to desorption of potassium from clay minerals (Kloppmann et al., 1998).

**Figure 2:** Piper diagram for the Chalk aquifer in the study area. Arrow 1 represents the modification of water chemistry in the south to the north in the western part of the study area. Arrow 2 represents the passage in captivity to the North East.



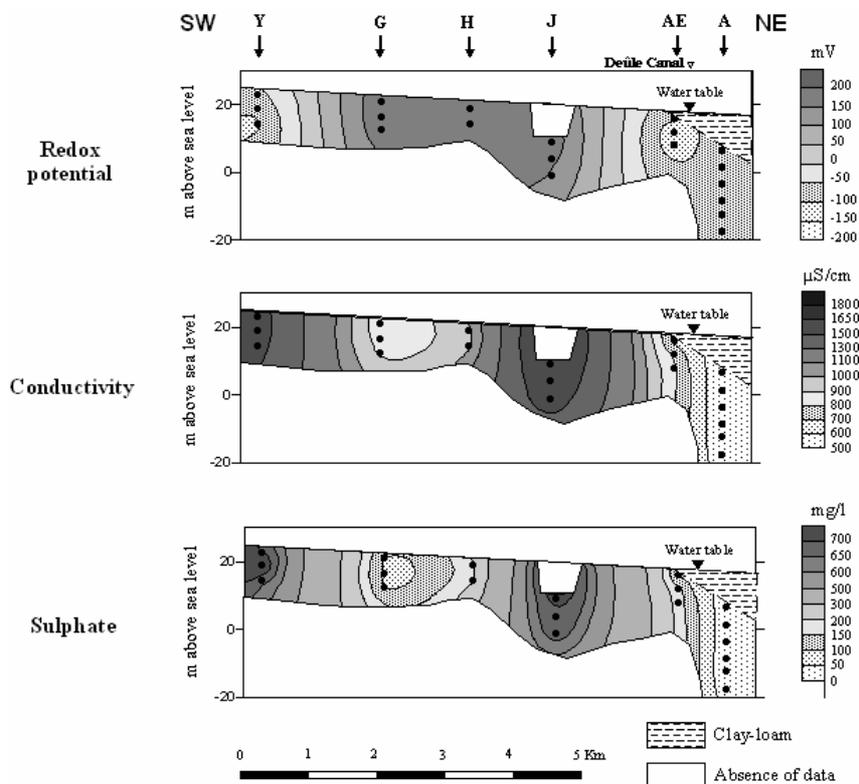
### Method

To access to the vertical concentration gradients, the monitoring boreholes are sampling by low-flow purging technique according to depth. Other advantage of this technique is the minimization of the turbidity caused by pumping. A high turbidity leads to mistakes for the measures of metals. The low-flow purging technique for the Chalk aquifer is described in Barrez et al. (2007). The samples are obtained with a flow rate (often < 3L/min) to minimize drawdown (<0.1 m) until field parameters stabilization and are spaced every 4-5 meters. For Wilson (1995), water sample is representative of the ambient groundwater when variations of temperature, conductivity, dissolved oxygen, pH do not respectively exceed  $\pm 0.5^{\circ}\text{C}$ ,  $\pm 10 \mu\text{S/cm}$ ,  $\pm 0.2 \text{ mg/L}$  and  $\pm 0.1 \text{ pH}$  unity. The field parameters (temperature, electrical conductivity, dissolved oxygen, redox potential and pH) are measured in steady state flow directly to the exit of pump. Before pumping, profiles of these parameters are also established by a multiparameter probe (KLL-Q SEBA). These two techniques are used to perform the understanding of the evolution of various contaminant plumes (e.g. sulphate).

### An example of “snap shot” of water quality

Evolution profiles for the Winter 2005 of redox potential, electrical conductivity, sulphate concentration are showed figure 3. The boreholes used are projected on line about perpendicularly to the global flow direction. In this area, the aquifer has a thickness > 50 m but the boreholes do not entirely cross aquifer. Here, the variations of the parameters are dual: in space and depth. It appears much less important according to depth because the horizontal and vertical scales are different. With the low-flow pumping according to depth it is possible to obtain a “snap shot” of the groundwater. On this area, the electrical conductivity is strongly influenced by sulphate concentration and provides an excellent way to detect sources of sulphate. On this example in Fig. 3, the concentration of sulphate seems to be homogeneous according to depth except for the boreholes Y and J. These two boreholes are located near a coal mine tip. From unconfined to confined zone, the process of sulphato-reduction leads to a decrease of sulphate concentration.

**Figure 3:** Evolution profiles of redox potential, conductivity and sulphate concentration. Samples are representing by points. For the first meters under the water table of the monitoring borehole J the casing is solid.



## Conclusion

In the coal basin of the Nord-Pas-de-Calais, the Chalk aquifer is strongly influenced by the old mining activity, industries and urbanization. Sampling according to depth could be important to perform the monitoring of the Chalk and to estimate the vertical distribution of contaminants. It could be a good way to minimize the mistakes of chemical measures when a borehole is sampling in only one point.

## Acknowledgements

Authors would like to thank the Nord-Pas-de-Calais Region and the European Union for their financial support (contracts nos. 105/2638 and N278/8497).

## References

- Barrez F, Mania J, Mansy JL, Robaszynski F (2007) Investigation of a chalk aquifer : advantages and limits of diffusion samplers and low-flow sampling techniques. *Hydrological Sciences Journal*, 52(4): 732-747.
- Bernard D (1979) Contribution à l'étude hydrogéochimique de l'aquifère de la craie dans le Nord de la France. Etat et acquisition du chimisme de l'eau. *Thèse, Université de Lille*: 179 p.
- Denimal S, Tribouvillard N, Barbecot F, Dever L (2002) Leaching of coal-mine tips (Nord-Pas-de-Calais coal basin, France) and sulphat transfer to the chalk aquifer: example of acid mine drainage in a buffered environment. *Environmental Geology* 42: 966-981
- Droz B (1985) Influence de la structure et de la nature des terrains du Valenciennois sur la qualité de l'aquifère de la craie (Nord de la France). Apport du krigeage à l'hydrochimie régionale et gestion qualitative des eaux souterraines. *Thèse, Université de Lille*.
- Kloppmann W, LL D, Edmunds W M (1998) Residence time of Chalk groundwaters in the Paris Basin and the North German Basin: a geochemical approach. *Applied geochemistry* 13: 593-606.
- Pauwels H, Talbo H (2004) Nitrate concentration in wetlands: assessing the contribution of deeper groundwater from anions. *Water Research* 38: 1019-1025.
- Vallée K (1999) Le nickel dans les eaux alimentaires: application aux champs captants du bassin Artois-Picardie. *Thèse de 3ème cycle, Lille*.
- Wilson, N (1995) *Soil and Ground Water Sampling*. CRC Lewis Publishers, Boca Raton, Florida, USA.