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The Dogger aquifer of Poitiers (France): groundwater quality and vulnerability

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Abstract. **This work focuses on the study of the Dogger aquifer in Poitou (France). This aquifer represents the main water resource for this region. Its resources are primarily used for drinking water supply in urban areas and for irrigation.**

The objectives of the study are to analyze the flow pattern of the groundwater (flow conditions, relationships with major rivers Clain and Vienne), the mineralization processes and its vulnerability to surface pollution.

Key-Words. **Dogger aquifer, Poitou region, Hydrochemistry, Vulnerability.**

I. INTRODUCTION

The Department of Vienne (Poitou-Charentes), located in west-center France (Fig.1) is supplied with water primarily from groundwater. The capital of the Department is the historical city of Poitiers. Total water volumes collected in 2010 amounted to 81 million m^3, and are mainly used for drinking water and agriculture (Table 1). 66 million m^3 are taken from groundwater, which is more than 80% of the total volume. Agriculture is the dominant economic activity in the region and uses 48 million m^3, which represents 60% of the total volume. Groundwater accounts for 81% of this volume. These statistics place great emphasis on the vital importance of groundwater for this region.

This work focuses on the study of the Dogger aquifer, located between the rivers Clain and Vienne. The surface of the study area is about 500 km^2. Piezometric campaigns and collection of groundwater samples were carried out during November 2012 to analyze the hydrodynamics (flow conditions, relationships with major rivers Clain and Vienne) and the mineralization processes of groundwater.

A preliminary analysis of this aquifer vulnerability to surface pollution was also undertaken, using the Drastic approach.

II. GEOLOGICAL CONTEXT

The study area is at the crossroads of four major geological units: the sedimentary formations of the Paris Basin in the north-east and the Aquitaine Basin in the south-west and the schist and granite massifs of the Armorican Massif to the north-west, and the Central Massif in the south east. The threshold of Poitou is at the interface of these units (Fig. 1).

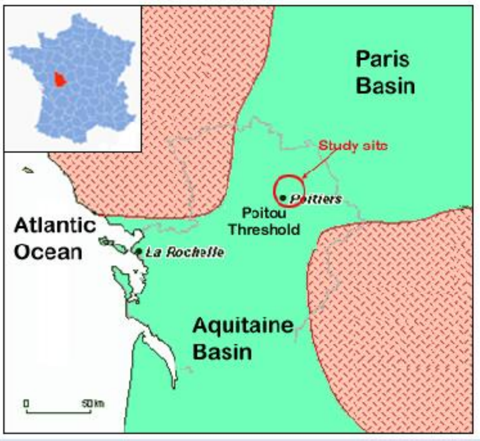

Figure 1. Location and geological context of the study site

Table 1. Volumes of water (Mm^3/year) used in the Department of Vienne in 2010/11. Source: SIGES

	Groundwater	Rivers	Total
Drinking water	27	6	33
Agriculture	39	9	48
	66	15	81

From a geological point of view, in the study area, the Mesozoic series covers the granite basement (intrusive granite set up at the end of the Hercynian orogeny) previously subjected to severe erosion. Above this basement, which outcrops locally in the valleys (Ligugé Champagné St Hilaire ...), lies the Lias series which consist of various facies (clay, sand, limestone and dolomites). The Infra-Toarcian contains a confined aquifer with a relatively thin (tens of meters) but karstic and fractured reservoir. It is confined under marly formations (Fig.2).

Above the Lias, lies the Dogger limestones in which karst is well developed. This karst massif is in the form of plateaus. The limestones are overlain by sandy clay soil, more or less thick, alteration products combined with fluvial and aeolian deposits. These formations, which cover almost all the Dogger, store rainwater but generally have poor permeability. They slowly supply with water the underlying karst aquifer as evidenced by the many karst figures (sinkholes, closed depressions ...) that can be observed. To the north, more recent formations outcrop : the Upper Jurassic limestones (Malm), and clays and limestones of Cretaceous.

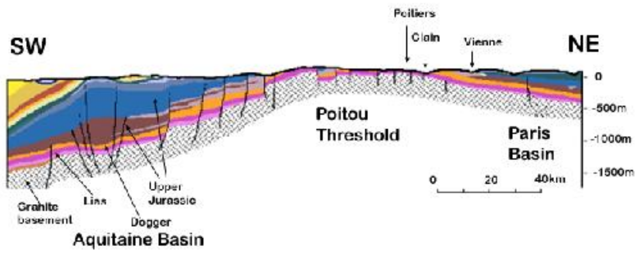

Figure 2. Geological SW-NE cross-section. Source BRGM, modified.

III. HYDROGEOLOGICAL CONTEXT

The two main aquifer systems consist of Lias and Dogger formations. These two aquifers are separated by Toarcian impermeable marl series.

The Lias aquifer, mainly confined, is unaffected by surface pollution. However, it has undesirable natural elements (fluorine, arsenic) which often exceed the standards for drinking water concentration.

The limestone aquifer of the Middle Jurassic (Dogger) is the main water resource whether for irrigation or drinking water. This particularly vulnerable karstic and unconfined aquifer, often has a poor quality (contamination by nitrates and pesticides from agriculture). The thickness of this aquifer is important to the north and south of the basin, but is strongly reduced in the central part (bulging of Poitou threshold) and even disappears completely at the Champagné Saint Hilaire and Liguge horsts (Fig.2).

Alluvial aquifers and that of the Cretaceous (Cenomanian), downstream of Poitiers, are unproductive.

Poitou-Charente is subject to a maritime climate with relatively mild winters and summers. The average rainfall is about 700 to 800 mm.

III. PIEZOMETRY OF THE DOGGER AQUIFER IN THE STUDY AREA

The Dogger aquifer has been the subject of several piezometric studies, which however, are very local and sectorial. A piezometric campaign has been conducted in November 2012. Around one hundred wells and boreholes have been inventoried and helped establish the piezometric map of the groundwater (Fig 3).

The piezometric map shows that the groundwater is drained by the Clain river to the West and the Vienne river to the East. A groundwater dividing line separates the basins of Clain and Vienne. However underground basins do not generally correspond to surface topographic watersheds.

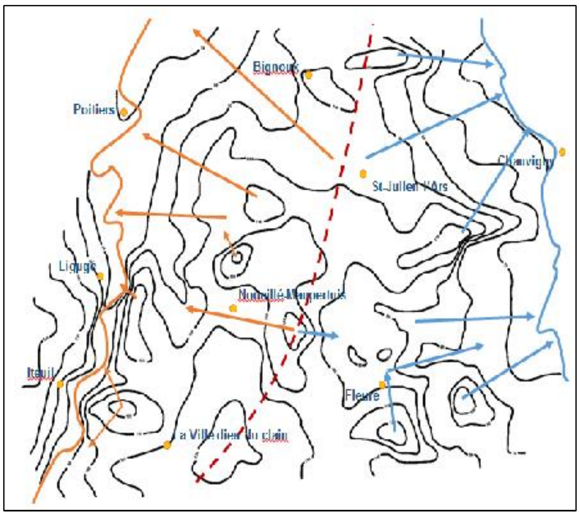

Figure 3. Piezometric map of the Dogger groundwater (November 2012)

IV. MINERALIZATION PROCESSES OF THE DOGGER GROUNDWATER.

During the campaign of November 2012, 56 water points were sampled. Major elements were measured : HCO_3 by titration, SO_4, Cl and NO_3 by chromatography and cations (Na, K, Mg, Ca) by atomic absorption.

The groundwater is moderately mineralized (average TDS = 616 mg/l) although in some areas there are high mineralization (maximum TDS = 1120 mg/l). The variability of some ions is very high. The coefficient of variation of Cl is the highest (CV = 118%), followed by K (CV = 117%). NO_3 , Mg and Na have a CV>70%. This shows that the mineralization of the groundwater is not homogeneous.

The matrix of correlations between the elements was calculated (not reported here). This matrix shows that not any ion is highly correlated with TDS. The correlations are of the same order of magnitude (0.38 <R < 0.59) except for sodium ($R_{TDS,Na}$ = 0.2). Significant correlations are of the same order of magnitude. $R_{Ca,\ HC03}$ = 0.49 and shows a dissolution of carbonate rocks. Conversely correlations $R_{SO4,Na}$ = 0.55, $R_{Cl,Ca}$ = 0.51 show associations which result from processes other than simple dissolution of rocks.

The Piper diagram (Fig. 4) shows that, calcium bicarbonate, in relative values, is the dominant facies, in relation with the limestone nature of the reservoir.

A principal component analysis was performed on data expressed in mg/l. This multivariate analysis provides a deeper insight into the associations between the elements. The first two components accounted for 54% of the total variance of the original data and are sufficient to explain the variability in the data. The plan of these two CP (Fig. 5) shows the relationship between the variables. F1 axis shows an opposition between Na and all the other elements. F2 axis discriminates a group (HCO_3, Ca and NO_3) and a group (Cl, SO_4, Mg and K). The association (HCO_3, Ca) has been discussed previously. Other associations indicate a complex hydrochemistry, briefly discussed below.

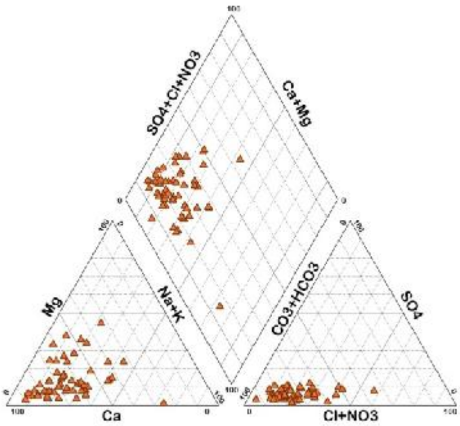

Figure 4. Piper Diagram of the water samples taken in November 2012

The waters on their way during recharge, flow through the calcareous and clayey Pliocene formations which cap the Dogger limestone and which result from weathering of these limestone. The Dogger reservoir is itself karstified and the conduits can be lined with clays. The waters are thus in contact with clays as well during recharge as when they flow in the aquifer. Transformations by bases exchanges are likely to occur. The bases exchange index, following the expression of Schoeller (Schoeller , 1977) was calculated for all samples. This index is negative with high values. This reflects a strong influence of base exchange processes according to the equation below:

$$\text{Ca (water)} + \text{2Na-clay} \rightarrow \text{Ca-clay} + \text{2Na(water)}$$

We noted above the absence of any significant correlation between Na and other elements, particularly anions. Na may originate from the base exchange processes described above.

The region is agricultural, the presence of nitrates in the groundwater can be related with the use of fertilizers. High nitrate levels show the intensive use of fertilizers. It also explains to some extent, the presence of elements such as K, Mg, Cl and SO_4.

V. VULNERABILITY AND DIFFUSE CONTAMINATION OF THE DOGGER GROUNDWATER BY NITRATES

Figure 6 shows a mapping of NO_3 content in the groundwater. It brings out the degraded state of the groundwater quality. Indeed it appears that on a large part of the aquifer, the NO_3 concentrations exceed the standard limit of 50 mg / l.

The transfer of nitrates to the groundwater, and the consequent vulnerability of groundwater to surface pollution, depends on the transport properties of the soil, the unsaturated zone and the saturated aquifer. A detailed study of these properties would require relatively large means (pumping tests, tracer tests, analyzes of soil, of the unsaturated zone, etc.).

As the vulnerability of groundwater is a fundamental factor within the management of water resources, simpler methods for characterizing vulnerability have been developed since the 70s. The Drastic approach (Aller et al, 1987), which is a weighted index method (Baalousha, 2006; Sinan and Razack, 2009) has been widely used for this purpose. An application of this method was made to the Dogger groundwater, as a first attempt to characterize the vulnerability of the aquifer.

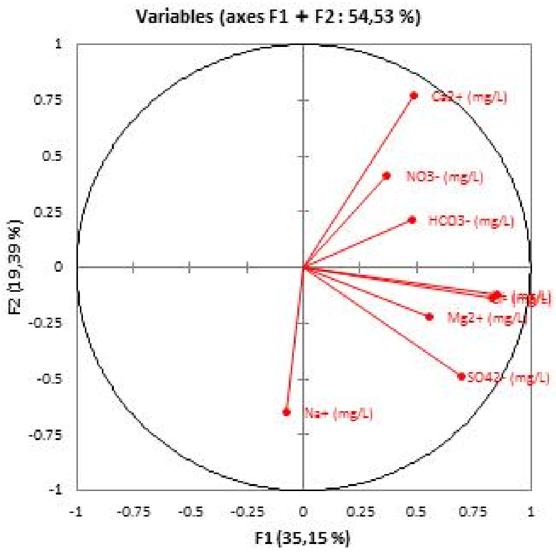

Figure 5. Principal Component Analysis. Plot of the variables on the F1-F2 plane

The method is well known and takes into account the following parameters (Depth, Recharge, Aquifer lithology, Soil, Topography, Impact of Unsaturated zone hydraulic Conductivity) and assigns weights. Drastic index is made up of a sum of product of the rating and weights for these parameters. Note that, in the present work, some important parameters (recharge , hydraulic conductivity) were taken from the literature. The Drastic vulnerability map of the Dogger groundwater is shown in Figure 7.

Comparing nitrate contamination and Drastic vulnerability maps (Fig. 6 and 7) reveals rather high discrepancy between these two parameters. This indicates a limitation of the Drastic method under certain conditions. An important limitation of Drastic, is that the method does not take into account the processes of contaminant transport. The work begun here will be further continued by developing a numerical modeling of nitrate transport in the aquifer.

VI. CONCLUDING REMARKS

Further works are required to understand and model the vulnerability of the Dogger system in the Poitou region. It appears that the vulnerability is rather a complex concept to define in heterogeneous systems as the Dogger aquifer. Coming efforts will be directed towards a numerical modeling of physical processes of flow and contaminant transport in this system.

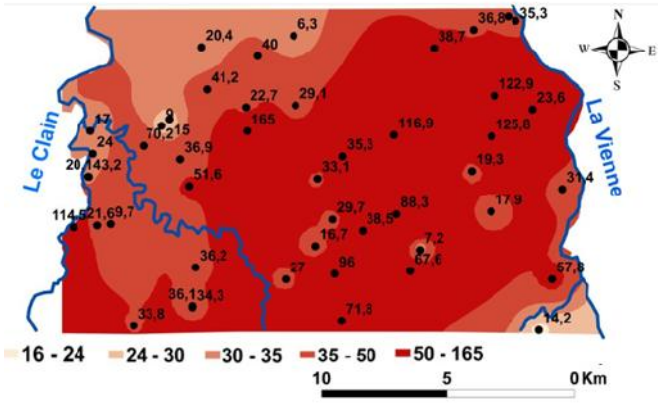

Figure 6. Map of the nitrate contents in the groundwater (November 2012)

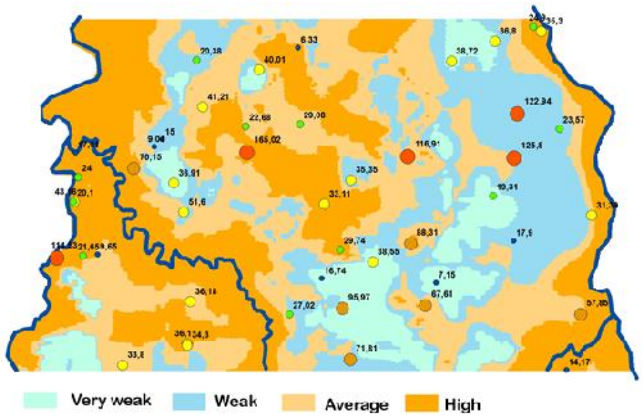

Figure 7. Vulnerability map of the Dogger groundwater according to Drastic approach

REFERENCES

Aller L., Bennet T., Lehr J., Petty R., Hackett G. (1987). DRASTIC : A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings. EPA-600/2-87-035, 455 p.

Baalousha H. (2006). Vulnerability assessment for the Gaza Strip,Palestine using DRASTIC. Environ Geol. 50: 405–414

Sinan M & Razack M. (2009) An extension to the DRASTIC model to assess groundwater vulnerability to pollution: application to the Haouz aquifer of Marrakech (Morocco). Environmental Geology, 57, 349-363.

Schoeller H (1977) Geochemistry of groundwater. In: Brown RH et al (eds) Groundwater studies—an international guide for research and practice. UNESCO, Paris, pp 1–18