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Hydrogeochemistry of three Wetland Ecosystems in River Valleys in Flanders, Belgium

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Introduction

In Flanders, North-Belgium, wetland ecosystems in river valleys play an important role in the preservation of biodiversity. Therefore, their study has been a priority within the framework of the Flemish governmental impulse program for nature conservation and development (VLINA). In one of the research projects, conducted within this program, the relationships between nature quality (*i.e.* vegetational diversity) and soil and water characteristics of three Flemish river basin wetlands were examined in particular (Batelaan *et al.*, 2000; Huybrechts *et al.*, 2000). These wetlands were the Doode Bemde in the valley of the Dijle River, the Vorsdonkbos in the valley of the Demer River, and the Valley of the Zwarte Beek, a tributary to the Demer River (figure 1).

This abstract presents the part of the project concerning the hydrogeochemistry of the investigated wetlands. As these wetlands are predominantly fed by discharging groundwater, the groundwater chemistry will probably be one of the major controlling factors for the vegetation. Hence, it was important to examine the different characteristics, origins and hydrogeochemical evolutions of the groundwater within and around the wetlands.

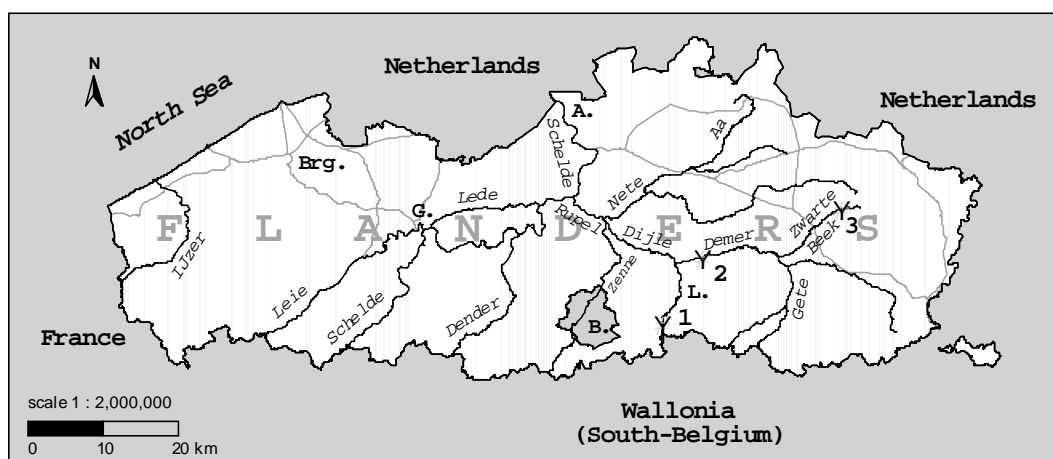


Figure 1. Location map of the three examined river basin wetland ecosystems. 1 = Doode Bemde, 2 = Vorsdonkbos, and 3 = Valley of the Zwarte Beek. B. = Brussels, A. = Antwerp, G. = Ghent, Brg. = Bruges, and L. = Louvain.

Geological and hydrological setting

The groundwater discharging into the wetlands, was recharged in the surrounding hills. Subsequently, it was transported through heterogeneous sandy aquifers towards the wetlands. In the Doode Bemde these aquifers belong to the Brussels Formation. In the Valley of the Zwarte Beek they belong to the Diest Formation and in the Vorsdonkbos to both. The groundwater from the Brussels Formation was expected to be more lithotrophic (mineral rich, *i.e.* calcereous), whereas that from the Diest Formation was expected to be more atmospheric (oligotrophic). Both formations, but the Diest Formation in particular, contain significant amounts of glaucony, a reactive iron-bearing clay mineral, that releases its iron content upon weathering (*cf.* Keppens, 1981; Van Ranst & De Coninck, 1983).

Groundwater analysis

Within each of the wetlands, about 50 piezometers were placed, with groundwater filters at a depth of about 2 m. The shallow groundwater in these piezometers was sampled and analysed for its main constituents. In addition, within or nearby the recharge areas of the Doode Bemde and the Vorsdonkbos, the deeper groundwater in existing piezometers (depths up to 104 m) will be sampled and analysed. For a number of drinking-water production wells (VMW, 1999), and for some other piezometers, located nearby the wetlands, groundwater quality data were available already. For comparison, rainwater and surface-water quality data (Huybrechts & De Becker, 1997; VMM, 1999) have been used as well.

Groundwater types

The analysis results for the (shallow) groundwater within the wetlands were subjected to a cluster analysis to differentiate between a number of characteristic groundwater types. In total, five groundwater types could be distinguished (see figure 2 and table 1). The acidic groundwater type 1a occurs only along the hill side of the wetlands, the comparable (somewhat less acidic) type 1b also more inside the valleys. In the Vorsdonkbos these groundwater types dominate. In the calcareous types 2 and 3 calcium and bicarbonate ions dominate, in type 4 calcium and sulphate ions dominate. Type 2, which is dominant in the Valley of the Zwarte Beek, has the lowest ionic concentration of all, type 4 the highest. Type 3, that dominates in the Doode Bemde, has the highest average pH. In all three wetlands, but mainly in groundwater type 3 and 4 of the Doode Bemde, elevated iron concentrations (up to 108 mg/l) occur.

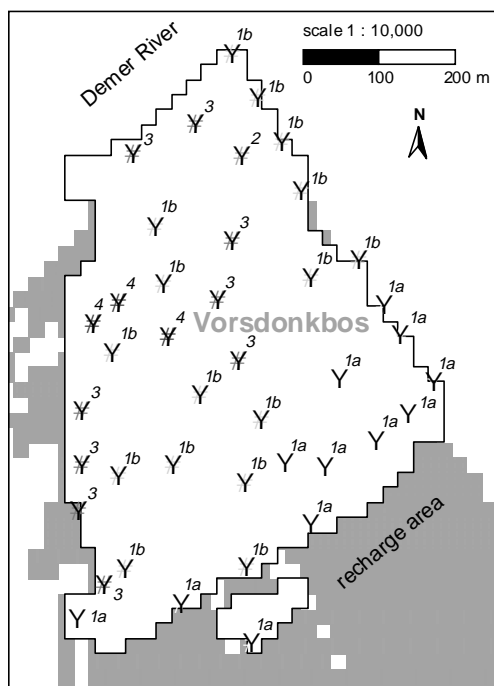


Figure 2. Distribution of groundwater types in the Vorsdonkbos. The surrounding recharge area is indicated in grey.

Table 1. Main characteristics of groundwater types in the three examined wetland ecosystems

water type	pH	EC μS/cm	dominant cation	dominant anion
1a	5.5	371	Ca ²⁺	none
1b	6.2	398	Ca ²⁺	none
2	6.3	160	Ca ²⁺	HCO ₃ ^{-*}
3	6.8	436	Ca ²⁺	HCO ₃ ^{-*}
4	6.7	867	Ca ²⁺	SO ₄ ²⁻ *

Van Wirdum's classification

For further classification of the groundwater types, all available analysis results were plotted in Van Wirdum's diagrams (figure 3). In a Van Wirdum's diagram, the ionic ratio (*IR*) is plotted against the electric conductivity (*EC*), where $IR = [Ca^{2+}] / ([Ca^{2+}] + [Cl^{-}])$ with concentrations expressed in meq/l. The *EC* can be seen as a measure for the salinity, the *IR* as a measure for the dominance of calcium among the cations. As this dominance will be the result of geochemical processes, the *IR* can be seen as a measure for the geochemical processes that occurred

within the aquifers. Based on the position in the Van Wirdum's diagram, the groundwater can be classified as atmospheric, lithotrophic, thalassotrophic (marine) or anything in between (Van Wirdum, 1980).

From figure 3 it is clear, that in the Vorsdonkbos groundwater type 1a is atmospheric to slightly lithotrophic. This points towards limited, shallow groundwater-flow systems with a low degree of mineralisation. The other groundwater types appear to be predominantly lithotrophic. Hence, these types could be part of more extended, deeper groundwater-flow systems. In particular for groundwater type 3, this appears to be true.

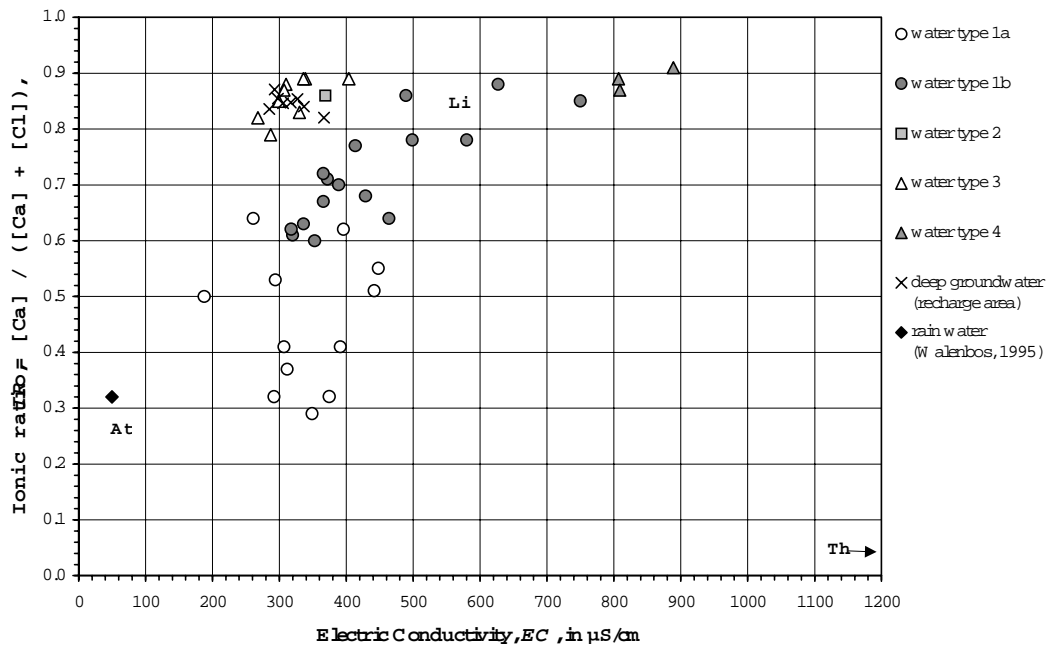


Figure 3. Van Wirdum's diagram for shallow groundwater in the Vorsdonkbos, classified per groundwater type, for deep groundwater in its recharge area (VMW, 1999), and for rainwater from the nearby Walenbos (Huybrechts & De Becker, 1997). At = atmospheric, Li = lithotrophic, and Th = Thalassotrophic (marine) groundwater.

Saturation towards minerals

Using the hydrochemical calculation program PHREEQC (Parkhurst & Appelo, 1999), for each groundwater type and each individual groundwater sample the saturation indices (*SI*) were calculated for about 40 minerals and 6 gasses (like CO₂). A positive *SI* indicates that the groundwater is (over)saturated towards the mineral or gas in concern. If so, such a mineral or gas might have played a role in the geochemical processes occurring within the aquifers.

Within the wetlands, most groundwater types and samples were saturated towards iron (hydr)oxides, such as hematite (Fe₂O₃), goethite (FeOOH), and magnetite (Fe₃O₄). This was not surprising, as the orange precipitates of these minerals in the ditches is characteristic for the wetlands. In the Vorsdonkbos and the Valley of the Zwarte Beek groundwater type 1a was undersaturated towards these minerals (*SI* < 0), in the Valley of the Zwarte Beek also the dominant groundwater type 2. Where the groundwater is undersaturated towards the iron (hydr) oxides, it was frequently saturated towards pyrite, particularly along the hill sides. Hence, if pyrite is present, its dissolution can play a role in limited, shallow groundwater-flow systems.

Saturation towards calcite (CaCO₃) occurred however in a few samples, but generally only the groundwater of types 3 and 4 came close to saturation. This could indicate a relationship between these groundwater types are deeper groundwater-flow systems, comprising the Brussels Formation, where calcite dissolution might occur. Even in groundwater type 4 saturation towards gypsum (CaSO₄·2H₂O) was not observed.

Mineralogy

A number of sand samples from the aquifers in the recharge areas of the wetlands is now subjected to a mineral research by X-ray diffraction techniques. Results are expected soon. The purpose of this research is to identify reactive minerals (in particular glaucony and its weathering products), that might have played a role in the geochemical processes within the aquifers.

Geochemical processes

With the inverse-modeling option of PHREEQC (Parkhurst & Appelo, 1999), it is possible to calculate from the analysis results of groundwater samples along a groundwater-flow path what geochemical processes might have caused the hydrochemical differences between them. These model calculations will be carried out as soon as all analysis results have been obtained.

Acknowledgements

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