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Isotope tools to support conceptual model building of the Carboniferous limestone aquifer of Northern France and Belgium

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Since the beginning of the 20th century, the Carboniferous aquifer was known as a high potential limestone aquifer. Groundwater has been exploited for decades to provide drinkable water and supply heavy factories in north of France and Belgium. Over-pumped during the last century, the Carboniferous aquifer has seen its water level dramatically decreased between Lille (Fr), Mouscron and Tournai (Be). Since the end of industrial period and some agreements to reduce pumpings, groundwater consumption has declined and water table is now stabilized and slowly coming back to a more “natural” level in some areas. In order to sustainably manage this aquifer, French and Belgian environmental agencies and local authorities underlined the need of a better hydrogeological knowledge. Within the framework of the “Scaldwin” project (launched in 2008), a hydrogeological model will be built. To reach these objectives, existing data were compiled, updated and treated. Moreover, new data were collected since 2009: 11 boreholes were drilled, 2 piezometrical maps were drawn and 2 field sampling campaigns were carried out in March and November 2011 to collect groundwater for further analyses.

As a first step, the conceptual hydrogeological map was reviewed considering new knowledge of the geometry and water levels of this aquifer. Then, the hydrogeochemical study was undertaken in order to dispel doubts on some specific aspects such as: relationships between the deep (carbonated Carboniferous) and the surface (chalky Cretaceous) aquifers, delineation of the southern Carboniferous aquifer limit, mechanisms of sulphate enrichment… Major and trace elements, dissolved gases (CFC-11, CFC-12, CFC-113, SF6) and various isotopes (δ2H, δ18O, δ11B, δ34S, δ18O-SO4, δ13C, 14C) were analysed in water sampled from 36 wells exploiting the Carboniferous limestones (16 in the French part and 20 in Belgium) and 4 waters from the chalk aquifer.

Cation exchange process is playing an important role in the chemical evolution of water from the recharge to the discharge area. Age-dating tools confirmed the extension of the recharge area in the East and highlighted the presence of paleowater in the southern part of the aquifer. This sector is poor in boreholes and wells and seems to be hydrogeologically quite isolated from the rest of the Carboniferous aquifer. Groundwater are there enriched in sulphate. Sulphate isotopes showed that these compounds have two main sources within the aquifer. In the southern part (mainly old water), anhydrites dissolution has a more important fingerprint of groundwater as observed near Saint-Ghislain (Be) by various authors. In the recharge area and the northern part, pyrite/marcasite oxidation is the dominating process allowing the groundwater enrichment in SO4. Furthermore, bacterial reduction activity is influencing isotopic signatures. Stable water isotopes data confirmed the presence of old water. The stable isotopes values of the Carboniferous aquifer water are varying from -7 ‰ (present day recharge, such as the chalk aquifer) and -8.6 ‰ (paleowater) depending on their position along the main flow lines and possibly interaction between chalk and Carboniferous aquifers. All these chemical processes should be considered in building the future hydrogeological model.